# ANNUAL REPORT

OF THE

# BOARD OF REGENTS

OF THE

# SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION
OF THE INSTITUTION

TO

JULY, 1891.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1893.

FIFTY-SECOND CONGRESS, FIRST SESSION.

*Concurrent resolution adopted by the Senate, July 22, 1892, and by the House of Representatives, August 5, 1892.*

*Resolved by the Senate (the House of Representatives concurring),* That there be printed of the Reports of the Smithsonian Institution and of the National Museum for the year ending June 30, 1891, in two octavo volumes, 10,000 extra copies; of which 1,000 copies shall be for the use of the Senate, 2,000 copies for the use of the House of Representatives, 5,000 copies for the use of the Smithsonian Institution, and 2,000 copies for the use of the National Museum.

# LETTER

FROM THE

# SECRETARY OF THE SMITHSONIAN INSTITUTION,

ACCOMPANYING

*The annual report of the Board of Regents of the Institution to the end of June, 1891.*

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SMITHSONIAN INSTITUTION,
*Washington, D. C., July 1, 1891.*

*To the Congress of the United States:*

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1891.

I have the honor to be, very respectfully, your obedient servant,

S. P. LANGLEY,
*Secretary of Smithsonian Institution.*

Hon. LEVI P. MORTON,
*President of the Senate.*

Hon. THOMAS B. REED,
*Speaker of the House of Representatives.*

# ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION TO THE END OF JUNE, 1891.

SUBJECTS.

1. Proceedings of the Board of Regents for the session of January, 1891.

2. Report of the Executive Committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, and receipts and expenditures for the year 1890–'91.

3. Annual report of the Secretary, giving an account of the operations and condition of the Institution for the year 1890–'91, with statistics of exchanges, etc.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge.

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## MEMBERS EX OFFICIO OF THE "ESTABLISHMENT."

(January, 1891.)

BENJAMIN HARRISON, President of the United States.
LEVI P. MORTON, Vice-President of the United States.
MELVILLE W. FULLER, Chief-Justice of the United States.
JAMES G. BLAINE, Secretary of State.
WILLIAM WINDOM, Secretary of the Treasury.
REDFIELD PROCTOR, Secretary of War.
BENJAMIN F. TRACY, Secretary of the Navy.
JOHN WANAMAKER, Postmaster-General.
WILLIAM H. H. MILLER, Attorney-General.
CHARLES E. MITCHELL, Commissioner of Patents.

## REGENTS OF THE INSTITUTION.

(List given on the following page.)

## OFFICERS OF THE INSTITUTION.

SAMUEL P. LANGLEY, *Secretary.*

*Director of the Institution and of the U. S. National Museum.*

G. BROWN GOODE, *Assistant Secretary.*

## REGENTS OF THE SMITHSONIAN INSTITUTION.

By the organizing act approved August 10, 1846 (Revised Statutes, Title LXXIII, section 5580), "The business of the Institution shall be conducted at the city of Washington by a Board of Regents, named the Regents of the Smithsonian Institution, to be composed of the Vice-President, the Chief-Justice of the United States [and the Governor of the District of Columbia], three members of the Senate, and three members of the House of Representatives, together with six other persons, other than members of Congress, two of whom shall be resident in the city of Washington, and the other four shall be inhabitants of some State, but no two of the same State."

### *REGENTS FOR THE YEAR 1891.*

The Chief-Justice of the United States:
MELVILLE W. FULLER, elected Chancellor, and President of the Board January 9, 1889.

The Vice-President of the United States:
LEVI P. MORTON.

| United States Senators: | Term expires. |
|---|---|
| JUSTIN S. MORRILL (appointed February 21, 1883) | Mar. 3, 1891. |
| SHELBY M. CULLOM (appointed March 23, 1885, and Mar. 28, 1889) | Mar. 3, 1895. |
| RANDALL L. GIBSON (appointed Dec. 19, 1887, and Mar. 28, 1889) | Mar. 3, 1895. |
| **Members of the House of Representatives:** | |
| JOSEPH WHEELER (appointed Jan. 5, 1888, and Jan. 6, 1890) | Dec. 23, 1891. |
| BENJAMIN BUTTERWORTH (appointed January 6, 1890) | Dec. 23, 1891. |
| HENRY CABOT LODGE (appointed January 6, 1890) | Dec. 23, 1891. |
| **Citizens of a State:** | |
| HENRY COPPÉE, of Pennsylvania (first appointed Jan. 19, 1874) | Dec. 26, 1891. |
| JAMES B. ANGELL, of Michigan (first appointed Jan. 19, 1887) | Jan. 19, 1893. |
| ANDREW D. WHITE, of New York (first appointed Feb. 15, 1888) | Feb. 15, 1894. |
| [Vacancy.] | |
| **Citizens of Washington:** | |
| JAMES C. WELLING (first appointed May 13, 1884) | May 22, 1896. |
| MONTGOMERY C. MEIGS (first appointed December 26, 1885) | Dec. 26, 1891. |

*Executive Committee of the Board of Regents.*

JAMES C. WELLING, *Chairman*. HENRY COPPÉE. MONTGOMERY C. MEIGS.

# JOURNAL OF PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION.

SMITHSONIAN INSTITUTION,
*Washington, January 28, 1891.*

In accordance with a resolution of the Board of Regents of the Smithsonian Institution, fixing the time of the beginning of the annual session on the fourth* Wednesday of January in each year, the Board met to-day at 10 o'clock A. M.

Present, Chief-Justice FULLER, Chancellor of the Institution, Hon. J. S. MORRILL, Hon. S. M. CULLOM, Hon. R. L. GIBSON, Hon. H. C. LODGE. Hon. JOSEPH WHEELER, Dr. HENRY COPPEE, Dr. JAMES C. WELLING, Gen. M. C. MEIGS, Dr. ANDREW D. WHITE, and the Secretary.

The minutes of the last meeting (January 8, 1890) were read and approved.

A letter from Dr. J. B. ANGELL was read, stating the reasons for his absence from the meeting.

The Secretary informed the Board that the following resolution had been passed by Congress and approved May 22, 1890:

No. 23. Joint resolution to fill vacancies in the Board of Regents of the Smithsonian Institution.

*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled*, That the vacancies in the Board of Regents of the Smithsonian Institution, of the class other than members of Congress, shall be filled by the appointment of Charles Devens, of Massachusetts, in place of Noah Porter, of Connecticut, resigned; and by the appointment of James C. Welling, of Washington City, whose term of office has expired.

Approved, May 22, 1890.

The Secretary read a letter from Judge Devens, September 20, 1890, declining the honor of the position of one of the Regents of the Smithsonian Institution, on account of a provision in the constitution of the State of Massachusetts, that "Justices of the supreme judicial court

*Resolution of the Board, January 8, 1890.

of the Commonwealth shall not hold any other place or office, or receive any pension or salary from any other State, government, or power whatever."

Judge Devens stated that were it not for this provision of law "it would have afforded" him "sincere pleasure to have been associated with the Regents and the Secretary in the administration of this great national trust for the diffusion of knowledge among men."

The Secretary stated to theBoard that since the receipt of this declination he regretted to announce the death of Judge Devens very suddenly on the 7th of the present month.

Dr. Welling, chairman, presented the annual report of the executive committee for the year ending 30th June, 1890.

On motion the report was accepted.

On motion the following resolution was adopted:

*Resolved*, That the income of the Institution for the fiscal year ending June 30, 1892, be appropriated for the service of the Institution, to be expended by the Secretary, with the advice of the executive committee, upon the basis of the operations described in the last annual report of said committee, with full discretion on the part of the Secretary as to items of expenditures properly falling under each of the heads embraced in the established conduct of the Institution.

Doctor Welling, on the part of the Executive Committee, stated that he had a resolution to introduce, which he desired to preface by a few remarks.

The resolution of the committee, after certain verbal alterations, was adopted and is as follows:

*Resolved*, That the action of the Executive Committee, during the recess of the Board, in authorizing the Secretary of the Institution to act for and in the name of the Regents in all matters pertaining to the National Zoölogical Park is hereby approved, and that the Regents authorize and direct the Secretary of the Institution to sign in their name all requisitions on the United States Treasury for the money appropriated by Congress for the National Zoölogical Park, and to approve for payment by the disbursing officer of the Smithsonian Institution all bills for services and supplies for said Park.

On motion, the following resolution was adopted:

Whereas Congress in the sundry civil act, approved August 30, 1890, made the following provision: "Repairs, Smithsonian Building: For fire-proofing the so-called chapel of the west wing of the Smithsonian Building, and for repairing the roof of the main building and the ceiling and plastering of the main hall of the building, $25,000, said work to be done under the supervision of the Architect of the Capitol with the approval of the Regents of the Smithsonian Institution, and no portion of the appropriation to be used for skylights in the roof nor for wellhole in the floor of the main building:" Therefore,

*Resolved*, That the Regents of the Smithsonian Institution hereby authorize the Secretary of the Institution to sign all requisitions on the United States Treasury for the money appropriated by Congress (sundry civil appropriation act, approved August 30, 1890) for repairs,

Smithsonian Building, to approve of plans submitted by the Architect of the Capitol, and to certify to all vouchers for payments by the Treasury Department for work done or materials furnished for said repairs.

The Secretary called attention to an estimate he had submitted to Congress at the beginning of the session in relation to an astro-physical observatory as follows:

*Astro-physical Observatory, Smithsonian Institution.*—Maintenance of astro-physical observatory, under the direction of the Smithsonian Institution, within the limits of the National Zoölogical Park, including salaries of assistants and the purchase of additional apparatus (Submitted), $10,000.

NOTE.—An astro-physical observatory and laboratory exists now under every considerable civilized government but that of the United States which has none, except that the Institution commenced one on the most modest scale in 1888, which now occupies a temporary structure on the grounds south of the Smithsonian building. Private citizens have subscribed $10,000 for an astro-physical observatory under the charge of the Regents, in the hope that Congress would maintain it, and the Smithsonian Institution proposes, in this case, to contribute the most recent apparatus to the value of $5,000 more.

The sum now asked is to be applied to the completion of the plant and to pay the current expenses, including the salaries of three assistants, to be engaged in researches of great scientific and economic value, wholly distinct in apparatus, methods, and objects from the quite otherwise important ones of those of the U. S. Naval Observatory.

It seems proper to state that the present appropriation is not asked for as an introduction to a larger one later, but that owing to the scale on which it is proposed to found and maintain this small establishment, no larger appropriation is contemplated as necessary for many years at least.

He stated that if Congress saw fit to make the appropriation asked for, even if it did not set apart a site in the Zoölogical Park for the observatory, it would be desirable for the Board of Regents to take action in accordance with the suggestions made in his estimates and annual report.

On motion, it was—

*Resolved*, That if an appropriation should be made by Congress for the maintenance of an astro-physical observatory under the direction of the Smithsonian Institution, the Regents will expend for this purpose from money already donated to them $10,000 for the construction of buildings for said observatory whenever a suitable site shall be designated by Congress and obtained for the purpose, and will present to it suitable apparatus of the most recent construction, now in their charge, to the value of not less than $5,000.

The secretary stated that the following bill had been passed in the Senate of the United States on the 5th of April, 1890:

AN ACT to provide for the erection of an additional fireproof building for the National Museum.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That for an additional fireproof building for the use of the National Museum, three hundred feet

square, with two stories and a basement, to be erected by the Supervising Architect of the Treasury, under the direction of the Regents of the Smithsonian Institution, in general accordance with plans now on file with the Committee on Public Buildings and Grounds, on the southwestern portion of the grounds of the Smithsonian Institution, there shall be appropriated, out of any moneys in the Treasury not otherwise appropriated, the sum of five hundred thousand dollars; said building to be placed west of the Smithsonian Institution, with its north front on a line with the north front of the present Museum building, and constructed as far as practicable, after proper advertisement, by contract or contracts, awarded to the lowest responsible bidder, and all expenditures for the purposes herein mentioned shall be audited by the proper officers of the Treasury Department.

The Committee on Public Buildings in the House of Representatives had made on the 9th of January, 1891, a favorable report on this bill, and it had been submitted to the House as follows:

The Committee on Public Buildings and Grounds, to whom was referred the bill (S. 2740) for the erection of an additional fireproof building for the National Museum, submit the following report:

To demonstrate the pressing necessity for additional accommodations for the vast amount of materials which has been accumulated for exhibition in the National Museum it will, perhaps, be sufficient to present the communication of the Secretary of the Smithsonian Institution.

It may also be stated that in view of acquiring a large quantity of the exhibit of the World's Fair of 1892, as was the case in the exhibition of 1876, such material being presented by various foreign countries, the pressing necessities are clearly demonstrated.

Your committee therefore recommend the passage of the bill as amended.

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SMITHSONIAN INSTITUTION, U. S. NATIONAL MUSEUM,
*Washington, April 29, 1890.*

SIR: I have the honor to lay before you certain considerations setting forth the necessity of an additional building for the National Museum and respectfully request your attention to them and your recommendation to Congress that the money necessary for this purpose be appropriated.

A set of provisional plans for the proposed new building has already been prepared, and I understand that these are in the possession of your committee. They have been prepared with the utmost care and represent the results of exhaustive study, which has extended over several years, of the plans of the best modern museum buildings in Europe and America, nearly all of which have been personally inspected by officers of the Smithsonian Institution.

The proposed building will contain about 220,000 square feet and the net area available for exhibition space and for storage and office room would be between five and six acres. The exhibition space would thus be nearly three times as great as in the present buildings, in which only 80,000 square feet are available both for exhibition and storage purposes.

The total cost of the present building was $315,400, including expenditures for steam-heating apparatus, marble floors, water and gas fixtures, and electrical apparatus.

The proposed building can, I believe, be constructed at a proportionately smaller cost. I am not prepared to state the exact sum which would be necessary for its completion; but, from estimates already furnished by responsible contractors, I feel sure that $500,000, if not sufficient to complete it, would be all that would be required to be expended during the present year, and I would earnestly urge the desirability of appropriating this amount for the purpose in question.

The necessity for a new Museum building is caused by the large increase in the accessions to the collections. In 1882, the first year of active work in the present building, the Museum contained less than 195,000 specimens. This number has now been increased to nearly 3,000,000 specimens, and the increase during the past eight years has been more than half as large again as during the previous twenty-one years.

The collections of the Smithsonian Institution and of the Government are especially rich in representations of the natural history of this country. A careful estimate made at the end of the last fiscal year showed that there were at that time in the zoölogical collections 1,850,721 specimens, in the botanical collections 48,637 specimens, in the geological collections 106,766 specimens, in the paleontological collections 172,540 specimens, in the anthropological collections 651,868 specimens, and in the various collections illustrating the arts and industries 43,540 specimens. Since this estimate was made, it is probable that more than 50,000 specimens of all kinds have been received.

The natural-history collections include the zoölogical collections, the botanical collections, and the geological collections, in which are contained not only all the geological and mineralogical specimens, but also the greater portion of the paleontological material, the study of fossil animals and plants forming an essential feature of modern geological work.

The anthropological collections illustrate the history of mankind at all periods and in every land and also serve to explain the development of all human arts and industries. There are in addition considerable collections illustrating the processes and products of the various arts and industries, as well as the historical collections, which are of especial interest to a very large number of the visitors to the Museum on account of the associations of the objects exhibited with the personal history of representative men or with important events in the history of America.

It is also noteworthy that among the accessions of more recent years many collections of great extent have been received. Among these are the bequest of Dr. Isaac Lea, of Philadelphia, which contains 20,000 specimens of shells, besides minerals and other objects; the Jeffries collection of fossil and recent shells of Europe, including 40,000 specimens; the Stearns collection of mollusks, numbering 100,000 specimens; the Riley collection of insects, containing 50,000 specimens; the Catlin collection of Indian paintings, and the collection of the American Institute of Mining Engineers.

In addition may also be mentioned the extensive collection obtained at the Fisheries Exhibitions at Berlin and London, at the New Orleans Cotton Centennial Exposition, and at the Ohio Valley and Central States Exposition. To these may be added the collections received annually from U. S. Fish Commission, the Geological Survey, the Bureau of Ethnology, and from many other Government departments and bureaus. These are very extensive and are yearly increasing in bulk and value.

There is in the present Museum Building no exhibition space available for the collection of reptiles, mollusks, insects, marine invertebrates, vertebrate and invertebrate fossils; and the space now afforded for the exhibition of the vast collections of fishes, birds' eggs, plants—fossil and recent—and the geological collections, aggregating not less than 350,000 specimens, is entirely inadequate.

In a letter addressed in 1888 to the chairman of the Senate Committee on Public Buildings and Grounds I endeavored to demonstrate the remarkable increase which had characterized the growth of the collections in the National Museum, and I there stated that in the five years between 1882 and 1887 the number of specimens in the collection had multiplied no less than sixteen times. Since 1887 the pressure for additional room has, of course, grown greater, and during the last year it has become necessary to decline many offers of collections for want not only of exhibition space, but even of storage room where they may be temporarily cared for.

The armory building, which for more than ten years had been used by the Museum for storage purposes, is now entirely occupied by the U. S. Fish Commission, with the exception of four rooms, used by some of the Museum taxidermists, who are now working in very contracted space, and whom it is impossible to accommodate elsewhere.

Every space is now filled to its utmost capacity, and no more collections of any considerable extent can be received until additional room is provided for their reception.

In a few words it may be stated that for exhibition, storage, and laboratory space 316,400 square feet are needed instead of 100,675 square feet, which now constitute the available area for all of these purposes.

In conclusion, I reaffirm without hesitation that unless additional space is provided it will be impossible to take any further important steps toward the improvement of the Government collections.

Your obedient servant,

S. P. LANGLEY,
*Secretary.*

Hon. SETH L. MILLIKEN,
*Chairman of the Committee on Public Buildings and Grounds, House of Representatives.*

In view of the probability of the passage by Congress of the bill providing for a new building for the Museum, it was—

*Resolved*, That the Executive Committee of the Board of Regents, or a majority thereof, and the Secretary, be, and they are hereby, authorized and empowered to act for and in the name of the Board of Regents in carrying into effect the provisions of any act of Congress that may be passed providing for the erection of a new building for the United States National Museum.

A memorial was read from Doulton & Co., of London, England, calling attention to the deposit in the institution in 1876 of certain articles of terra-cotta, the principal one being the colossal group "America," a copy of one of the marble groups by Bell on the pedestal of the Albert Memorial Monument in Kensington, and asking that the Board of Regents be pleased to recommend to the Government that an appropriation be made for the purchase of the goods now in their possession.

The whole subject had been carefully considered by the Executive Committee and was now submitted to the Board without recommendation.

After some discussion and inquiries by members of the Board of the Secretary and Chairman of the Executive Committee as to the value of the articles as works of art and the desirability of their acquisition for the Institution, it was—

*Resolved*, That the memorial of Doulton & Co. be re-referred to the Secretary with power to act.

The Secretary stated that he had been authorized by the President, the Vice-President, the Chief-Justice, and other members of the Establishment to ask for legislation the effect of which would be to modify the organic act so that the "Establishment" would consist of these high officials and of all the heads of Departments.

The proposed change . . . is covered by the following words:

*Be it enacted, etc.*, That "An act to establish the Smithsonian Institution for the increase and diffusion of knowledge among men," approved August 10, 1846, Revised Statutes, Title LXXIII, be, and the same is hereby, amended in section 5579 of said act, by striking out the words, "the Secretary of State, the Secretary of the Treasury, the Secretary of War, the Secretary of the Navy, the Postmaster-General, the Attorney-General, the Commissioner of the Patent-Office, and the Governor of the District of Columbia, and such other persons as they may elect honorary members," and inserting the words, "the heads of Executive Departments," so that the section will read:

SEC. 5579. The President, the Vice-President, the Chief-Justice, and the heads of Executive Departments are hereby constituted an establishment by the name of the "Smithsonian Institution" for the increase and diffusion of knowledge among men; and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions hereinafter contained, and no other.

The Secretary stated that in accordance with the instructions given him at the last meeting of the Board he had prepared the following memoranda relative to the re-imbursement of money expended by the Institution for the Governmental system of exchanges.

[Memorandum relative to the re-imbursement of the Smithsonian fund for expenditures on account of Government exchanges.]

At a meeting of the Board of Regents of the Smithsonian Institution on January 8, 1890, it was

*Resolved*, That the Regents instruct the Secretary to ask of Congress legislation for the repayment to the Institution of the amount advanced from the Smithsonian fund for Governmental service in carrying on the exchanges.

In pursuance of this instruction the Secretary has the honor to submit the following statement:

Under the act of Congress accepting a donation from James Smithson for "the increase and diffusion of knowledge among men," and giving effect to this trust by the foundation of the Smithsonian Institution, the Board of Regents in 1851 established a system of international ex-

change of the Transactions of learned societies and like works; but, in addition to such publications, it voluntarily transported between 1851 and 1867 somewhat over 20,000 packages of publications of the bureaus of the National Government at an estimated cost to the private funds of the Institution of about $8,000. This however was understood to be a voluntary service, and no request for its reimbursement has been made or is contemplated.

Congress however in 1867, by its act of March 2, imposed upon the Institution the duty of exchanging fifty copies of all documents printed by order of either House of Congress or by the United States Government or bureaus, for similar works published in foreign countries, and especially by foreign governments.

The Institution possessed special facilities and experience for such work, the propriety of its undertaking which, in the interests of the Government, is evident; but it was hardly to have been anticipated that the Government should direct this purely administrative service and make no appropriation for its support. Such however was the case, and with the exception of a small (presently to be noted) sum, returned by some bureaus, it was wholly maintained during the next thirteen years, or until the first appropriation to the Institution for Exchanges in 1881, at the expense of the private fund of James Smithson.

From January 1, 1868, to June 30, 1886, 292,483 packages containing these official Government publications, having little to do with the object to which Congress devoted the Institution's private funds, were transported by the exchange bureau at a *pro rata* cost of $92,943,36, of which $29,706.85 accrued between 1881, when the first specific appropriation was made, and 1886. Of this $92,943.36, $19,302.35 was returned from various departments and bureaus, leaving a balance of $73,641.01 expended in carrying exclusively governmental publications.

What has preceded refers to the transportation of official documents, and not to that of Transactions of learned societies and other like works; but it is now necessary to mention that in 1878 the honorable Secretary of State designated the Smithsonian Institution as the special agent of the United States Government for carrying out the provisions of an international convention at Paris, which made the respective Governments assume the cost, not only of the transportation of official documents, but of scientific and literary publications between the States interested, and it would seem that Congress itself adopted this view of its responsibility, for from July 1, 1881, to June 30, 1886, while the Congressional and bureaucratic exchange represented a *pro rata* cost of $29,706.85, and the scientific publications $39,034.90, Congress appropriated directly $35,500—somewhat more than the cost of the Government exchange, but leaving a balance of $3,534.90 for scientific and literary exchanges unpaid. This latter sum, $3,534.90, added to the $73,641.01 mentioned above, makes a total of $77,175.91 for which, in equity, repayment might be requested.

In 1886, on the 15th of March, plenipotentiaries of the United States and various other nationalities signed a convention, more formal than that at Paris, by which the respective Governments definitely assumed the exchange of official documents and scientific and literary publications between the states interested.

The Institution prefers to adopt the latter date as a basis for its request rather than the earlier date, though, as mentioned above, equity would seem to allow it the entire sum expended for exchanges, at least since its official recognition by Congress in 1881 as the Government

exchange agent. No claim for the exchange of a purely scientific character is made for the years 1881 to 1886, so that the $35,500 that Congress appears to have appropriated for this end is treated as having a retro-active effect, and this amount deducted from the crude obligation of $73,641.01 leaves $38,141.01 as the amount due the private fund of James Smithson from 1868 to 1886.

Considering separately the period from July 1, 1886, to June 30, 1889, we find that the amount expended in these years under the direction of the Smithsonian Institution on account of international exchanges was $47,126.56; of this sum $37,000 were paid by Congressional appropriations, $3,091.75 were paid by Government Departments and others, and the balance, $7,034.81, by the Smithsonian Institution.

The action of the Board of Regents contemplates the presentation to Congress of a request to return to the Smithsonian fund the sums here shown to have been expended in the interests and by the authority of the National Government, namely, $38,141.01 in excess of appropriations advanced from January 1, 1868, to June 30, 1886, for the exchange of official Government documents, and $7,034.81 in excess of appropritions from July 1, 1886, to June 30, 1889, advanced for the purpose of carrying out a convention entered into by the United States, or an aggregate of $45,175.82.

### DRAFT OF BILL.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That the following sums be, and the same are hereby, appropriated, out of any moneys in the Treasury not otherwise appropriated, in repayment of moneys expended from the Smithsonian fund in exchanging with foreign countries the official publications of the United States Government, and in carrying out the provisions of a convention for the exchange of literary and scientific publications signed by a representative of the United States at Brussels, March fifteenth, eighteen hundred and eighty-six, namely:

SEC. 2. For exchanging the official publications of the United States Government from eighteen hundred and sixty-eight to eighteen hundred and eighty-six, as provided for by resolution seventy-two, Fortieth Congress, second session, the sum of thirty-eight thousand one hundred and forty-one dollars and one cent.

SEC. 3. For exchanging from July first, eighteen hundred and eighty-six, to June thirtieth, eighteen hundred and eighty-nine, official documents and scientific and literary publications, as provided for by the "convention between the United States of America, Belgium, Brazil, and other nations," concluded at Brussels March fifteenth, eighteen hundred and eighty-six, the sum of seven thousand and thirty-four dollars and eighty-one cents; in all, forty-five thousand one hundred and seventy-five dollars and eighty-two cents.

The foregoing memoranda had been placed in the hands of one of Regents in the House of Representatives, to present whenever it was deemed advisable, but no action had as yet, so far as the Secretary was informed, been taken.

The Secretary informed the Board that the executors of the late Dr. Jerome H. Kidder had refunded $100 to the Institution, which had been paid by the latter for legal services in relation to the bequest of Dr. Kidder to the Smithsonian, and the family of the testator did not

desire that "the action of the Regents in regard to the bequest should be attended by any financial burden to the Institution".

The announcement was made that a bequest of a medical library had been made to the Institution by Dr. Jonathan R. Bailey, of Olmstead, Ky., but the books had not yet been received.

A letter of thanks was submitted from Mrs. Cox, thanking the Board for the resolutions transmitted to her in regard to the death of her husband, the late honorable Samuel S. Cox.

The Secretary presented his annual report for the year ending June 30, 1890, which, in accordance with the instructions of the Board, had been printed and distributed to the Regents.

On motion the report was accepted.

Dr. Welling presented the following:

WHEREAS, The late George Bancroft was for several years a member of the Board of Regents of the Smithsonian Institution, and rendered useful service on its executive committee: Therefore, be it

*Resolved*, That while, for obvious reasons of propriety, we should abstain at this time and in this place from any full or formal commemoration of the manifold titles to distinction which clustered around the head of our late illustrious colleague, we can not forbear from testifying the special gratitude we owe to him for the interest he ever took in the welfare of this Institution, nor can we forbear from associating ourselves with the grief of his fellow-citizens throughout the length and breadth of the land, now that, in the fullness of his years and in the fullness of his honors, he has been called to rest from the labors which brought to him such a revenue of fame, alike in the walks of high executive administration, of diplomacy, and of literature.

The resolution was adopted by a rising vote.

On motion, the Board then adjourned *sine die.*

# REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION.

FOR THE YEAR ENDING JUNE 30, 1891.

*To the Board of Regents of the Smithsonian Institution:*

Your executive committee respectfully submits the following report in relation to the funds of the Institution, the appropriations by Congress, and the receipts and expenditures for the Smithsonian Institution, the U. S. National Museum, the International Exchanges, the Bureau of Ethnology, the National Zoölogical Park, the purchase of the Perkins collection of prehistoric copper implements, the payment to daughters of the late Prof. Joseph Henry, and the purchase of the Capron collection of works of Japanese art, for the year ending 30th June, 1891, and balances of former years.

## SMITHSONIAN INSTITUTION.

### *Condition of the fund July 1, 1891.*

The amount of the bequest of James Smithson deposited in the Treasury of the United States, according to act of Congress of August 10, 1846, was $515,169. To this was added by authority of Congress February 8, 1867, the residuary legacy of Smithson, savings from income and other sources, to the amount of $134,831.

To this also has been added a bequest from James Hamilton, of Pennsylvania, of $1,000; a bequest of Dr. Simeon Habel, of New York, of $500, and the proceeds of the sale of Virginia bonds, $51,500, making in all, as the permanent Smithson fund, $703,000.

*Statement of the receipts and expenditures from July 1, 1890, to June 30, 1891.*

RECEIPTS.

| | | |
|---|---|---|
| Cash on hand July 1, 1890, including cash from executors of Dr. Jerome H. Kidder, $5,000, and from Dr. Alex. Graham Bell, for astro-physical research, $5,000 | | $30, 192. 65 |
| Interest on fund July 1, 1890 | $21, 090. 00 | |
| Interest on fund January 1, 1891 | 21, 090. 00 | |
| | | 42, 180. 00 |
| | | 72, 372. 65 |
| Cash from sales of publications | 418. 36 | |
| Cash from repayments of freight, etc | 6, 344. 01 | |
| | | 6, 762. 37 |
| Total receipts | | 79, 135. 02 |

EXPENDITURES.

| | | | |
|---|---|---|---|
| **Building:** | | | |
| Repairs, care, and improvements | $1,972.71 | | |
| Furniture and fixtures | 837.36 | | |
| | | $2,810.07 | |
| **General expenses:** | | | |
| Meetings | 319.50 | | |
| Postage and telegraph | 325.70 | | |
| Stationery | 412.63 | | |
| General printing | 759.51 | | |
| Incidentals (fuel, gas, etc.) | 2,274.36 | | |
| Library (books, periodicals, etc.) | 1,660.87 | | |
| Salaries* | 18,322.21 | | |
| | | 24,074.78 | |
| **Publications and research:** | | | |
| Smithsonian Contributions | 318.82 | | |
| Miscellaneous Collections | 1,429.44 | | |
| Reports | 1,217.29 | | |
| Researches | 800.00 | | |
| Apparatus | 3,612.45 | | |
| Explorations | 57.40 | | |
| Museum | 871.03 | | |
| Zoölogical park | 499.42 | | |
| | | 8,805.85 | |
| Literary and scientific exchanges | | 3,382.21 | |
| Total expenditures | | | $39,072.91 |
| Balance unexpended June 30, 1891 | | | 40,062.11 |

The cash received from sales of publications, repayments for freight, etc., is to be credited on items of expenditure, as follows:

| | | | |
|---|---|---|---|
| Stationery | | $2.56 | |
| Postage and telegraph | | 28 | |
| General printing | | 75 | |
| Incidentals | | 528.68 | |
| Salaries | | 1,595.96 | |
| Smithsonian contributions | $64.25 | | |
| Miscellaneous collections | 310.25 | | |
| Reports | 43.86 | | |
| | | 418.36 | |
| Apparatus | | 111.50 | |
| Museum | | 733.21 | |
| Exchanges | | 3,371.07 | |
| | | | $6,762.37 |

The net expenditures of the Institution for the year ending June 30, 1891, were therefore $32,310.54, or $6,762.37 less than the gross expenditures, $39,072.91, above given.

All moneys received by the Smithsonian Institution from interest, sales, refunding of moneys temporarily advanced, or otherwise, are de-

*In addition to the above $18,322.21 paid for salaries under general expenses, $1,713.44 were paid for services, viz, $1,000.08 from the building account; $470.04 from the library account; $10 from the exchange account; and $233.32 from the Smithsonian Contributions account.

posited with the Treasurer of the United States to the credit of the Secretary of the Institution, and all payments are made by his checks on the Treasurer of the United States.

Your committee also presents the following statements in regard to appropriations and expenditures for objects intrusted by Congress to the care of the Smithsonian Institution:

## INTERNATIONAL EXCHANGES.

Appropriation by Congress for the fiscal year ending June 30, 1891, "for expenses of the system of international exchanges between the United States and foreign countries under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employés" (sundry civil act, August 30, 1890) .......... $17,000.00

*Expenditures from July 1, 1890, to June 30, 1891.*

| | | | |
|---|---|---|---|
| Salaries or compensation: | | | |
| 1 curator, 12 months, at $208.33 | | $2,499.96 | |
| 1 clerk, 7 months, at $150 | $1,050.00 | | |
| 5 months, at $160 | 800.00 | | |
| | | 1,850.00 | |
| 1 clerk, 3 months, at $110 | 330.00 | | |
| 9 months, at $120 | 1,080.00 | | |
| | | 1,410.00 | |
| 1 clerk, 3 months, at $80 | 240.00 | | |
| 9 months, at $85 | 765.00 | | |
| | | 1,005.00 | |
| 1 clerk, 3 months, at $75 | 225.00 | | |
| 9 months, at $80 | 720.00 | | |
| | | 945.00 | |
| 1 clerk, 12 months, at $75 | | 900.00 | |
| 1 clerk, 3 months, at $70 | 210.00 | | |
| 9 months, at $75 | 675.00 | | |
| | | 885.00 | |
| 1 stenographer, 12 months, at $45 | | 540.00 | |
| 1 clerk, 9 months, at $55 | | 495.00 | |
| 1 copyist, 3 months, at $35 | 105.00 | | |
| 9 months, at $45 | 360.00 | | |
| | | 465.00 | |
| 1 copyist, 13 days, at $1.50 | | 19.50 | |
| 1 copyist, 10 days, at $1 | | 10.00 | |
| 1 packer, 12 months, at $75 | | 900.00 | |
| 1 packer, 12 months, at $50 | | 600.00 | |
| 1 laborer, 3 months, at $45 | 135.00 | | |
| 9 months, at $50 | 450.00 | | |
| | | 585.00 | |
| 1 agent (Germany), 6 months, at $83.33⅓ | | 500.00 | |
| 1 agent (England), 6 months, at $41.66⅔ | 250.00 | | |
| 6 months, at $50 | 300.00 | | |
| | | 550.00 | |
| Total salaries or compensation | | | 14,159.46 |

| | | |
|---|---|---|
| General expenses: | | |
| Freight | $1,298.33 | |
| Packing boxes | 758.16 | |
| Printing and binding | 189.05 | |
| Postage | 184.58 | |
| Stationery and supplies | 410.42 | |
| | | $2,840.54 |
| Total expenditures international exchanges | | 17,000.00 |

NORTH AMERICAN ETHNOLOGY.

| | |
|---|---|
| Appropriation by Congress for the fiscal year ending June 30, 1891, "for continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employés" (sundry civil act, August 30, 1890) | $40,000.00 |
| Balance July 1, 1890, as per last annual report | 12,033.08 |
| | 52,033.08 |

The actual conduct of these investigations has been continued by the Secretary in the hands of Maj. J. W. Powell, Director of the Geological Survey.

*Ethnology:—Expenditures July 1, 1890, to June 30, 1891.*

| | |
|---|---|
| Salaries or compensation: | |
| 2 ethnologists, at $3,000 per annum | $6,000.00 |
| 1 archæologist, at $2,500 per annum, 10 months | 2,166.60 |
| 1 ethnologist, at $2,400 per annum | 2,400.00 |
| 1 ethnologist, at $2,400 per annum, 2 months | 400.00 |
| 1 archæologist, at $2,400 per annum, 2 months | 400.00 |
| 1 ethnologist, at $2,000 per annum, 10 months | 1,666.60 |
| 1 ethnologist, at $1,800 per annum, 2 months | 300.00 |
| 1 ethnologist, at $1,800 per annum | 1,800.00 |
| 1 ethnologist, at $1,800 per annum, 11 months | 1,650.00 |
| 1 assistant ethnologist, at $1,800 per annum, 5 months | 750.00 |
| 1 assistant archæologist, at $1,500 per annum, 2 months | 250.00 |
| 1 assistant ethnologist, at $1,500 per annum, 10 months | 1,250.00 |
| 1 assistant ethnologist, at $1,400 per annum, 2 months | 233.32 |
| 1 assistant ethnologist, at $1,400 per annum, 10 months | 1,166.60 |
| 1 assistant ethnologist, at $1,400 per annum, 10 months | 1,166.60 |
| 1 assistant ethnologist, at $1,200 per annum, 2 months | 200.00 |
| 1 assistant ethnologist, at $1,200 per annum | 1,200.00 |
| 1 assistant ethnologist, at $1,200 per annum, 9 months | 950.00 |
| 1 assistant ethnologist, at $1,200 per annum, 2 months | 200.00 |
| 1 stenographer, at $1,200 per annum, 10 months | 1,000.00 |
| 1 stenographer, at $1,000 per annum, 2 months | 166.66 |
| 1 assistant ethnologist, at $1,200 per annum, 2 months | 200.00 |
| 1 assistant ethnologist, at $1,000 per annum, 8 months | 666.64 |
| 1 assistant ethnologist, at $900 per annum, 2 months | 150.00 |
| 1 assistant ethnologist, at $900 per annum | 900.00 |
| 1 ethnologic aid, at $900 per annum, 2 months | 150.00 |
| 1 copyist, at $900 per annum | 900.00 |
| 1 copyist, at $900 per annum, 10 months | 750.00 |
| 1 copyist, at $720 per annum, 2 months | 120.00 |
| 1 copyist, at $720 per annum | 720.00 |

| | | |
|---|---|---|
| Salaries or compensation—Continued. | | |
| 1 modeller, at $720 per annum | $720.00 | |
| 1 modeller, at $720 per annum, 10 months | 600.00 | |
| 1 modeller, at $600 per annum, 2 months | 100.00 | |
| 1 clerk, at $600 per annum | 600.00 | |
| 1 clerk, at $600 per annum, 11 months 24 days | 590.00 | |
| 1 messenger, at $600 per annum, 8 months 7 days | 411.29 | |
| 1 modeller, at $480 per annum, 10 months | 400.00 | |
| 1 messenger, at $480 per annum, 3 months 8 days | 134.51 | |
| Unclassified or special jobs or contracts | 271.41 | |
| Total salaries or compensation | | $33,710.23 |
| Miscellaneous: | | |
| Traveling expenses | 2,354.76 | |
| Transportation of property | 290.20 | |
| Field subsistence | 115.16 | |
| Field supplies | 310.71 | |
| Field supplies for distribution to Indians | 93.54 | |
| Field material | .30 | |
| Laboratory material | 32.26 | |
| Books for library | 352.16 | |
| Stationery and drawing material | 309.00 | |
| Illustrations for reports | 840.35 | |
| Office furniture | 439.96 | |
| Office supplies and repairs | 193.41 | |
| Specimens | 174.10 | |
| | | 5,505.91 |
| Total expenditures | | 39,216.14 |
| Bonded railroad accounts settled by United States Treasury | | 42.70 |
| Total expenditure North American ethnology | | 39,258.84 |
| Balance July 1, 1891 | | 12,774.24 |

*Expenditures reclassified by subject-matter.*

| | | |
|---|---|---|
| Sign language and picture writing | 4,654.40 | |
| Explorations of mounds, eastern portion of United States | 4,978.58 | |
| Researches in archæology, southwestern portion of the United States | 8,497.82 | |
| Researches, languages of North American Indians | 12,412.73 | |
| Salaries, office of Director | 4,202.46 | |
| Illustrations for reports | 840.35 | |
| Researches among the Pueblos | 1,000.00 | |
| Contingent expenses | 2,629.80 | |
| | | 39,216.14 |
| Bonded railroad accounts settled by United States Treasury | | 42.70 |
| Total expenditure North American ethnology | | 39,258.84 |
| Balance July 1, 1891 | | 12,774.24 |

SUMMARY.

| | | | |
|---|---|---|---|
| July 1, 1890: | Balance on hand | 12,033.08 | |
| | Appropriation for North American ethnology | 40,000.00 | |
| | | | 52,033.08 |
| | Expended | | 39,258.84 |
| | Balance on hand July 1, 1891 | | 12,774.24 |

Which balance is deposited as follows:

| | |
|---|---|
| To credit of disbursing agents | $6,066.94 |
| In the United States Treasury | 6,707.30 |
| Balance on hand July 1, 1891 | 12,774.24 |

## NATIONAL MUSEUM.

### PRESERVATION OF COLLECTIONS, JULY 1, 1890, TO JUNE 30, 1891.

Appropriation by Congress for the fiscal year ending June 30, 1891, "for continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employés" (sundry civil act, August 30, 1890) ........ $140,000.00

*Salaries or compensation.*

| | |
|---|---|
| Direction: | |
| 1 Assistant Secretary of the Smithsonian Institution, in charge of the U. S. National Museum, 12 months, at $333.33 | $3,999.96 |
| Scientific staff: | |
| 1 curator, 12 months, at $200 | 2,400.00 |
| 1 curator, 12 months, at $200 | 2,400.00 |
| 1 curator, 12 months, at $200 | 2,400.00 |
| 1 curator, 12 months, at $175 | 2,100.00 |
| 1 curator, 12 months, at $175 | 2,100.00 |
| 1 curator, 12 months, at $150 | 1,800.00 |
| 1 curator, 2 months and 14 days, at $150 | 370.00 |
| 1 curator, 12 months, at $100 | 1,200.00 |
| 1 acting curator, 9 months, at $150 | 1,350.00 |
| 1 acting curator, 12 months, at $125 | 1,500.00 |
| 1 assistant curator, 12 months, at $133.33 | 1,599.96 |
| 1 assistant curator, 1 month, at $148.33; 2 months, at $145.32; 1 month, at $143.33; 1 month, at $142.33; 1 month, at $139.33; 1 month, at $137.33; 5 months, at $133.33 | 1,667.96 |
| 1 assistant curator, 3 months, at $125; 1 month, at $50 | 425.00 |
| 1 assistant curator, 12 months, at $100 | 1,200.00 |
| 1 assistant curator, 6 months and 25 days, at $140; 2 months, at $100 | 1,152.90 |
| 1 assistant, 2 months, at $150 | 300.00 |
| 1 assistant, 4 months, at $80 | 320.00 |
| 1 assistant, 5 months, at $65 | 325 00 |
| 1 aid, 12 months, at $80 | 960 00 |
| 1 aid, 12 months, at $80 | 960.00 |
| 1 aid, 12 months, at $75 | 900.00 |
| 1 aid, 1 month, at $75 | 75.00 |
| 1 aid, 12 months, at $65 | 780.00 |
| 1 aid, 1 month, at $60 | 60.00 |
| 1 aid, 5 months and 18 days, at $60 | 336.00 |
| 1 aid, 7 months and 14 days, at $60 | 448.00 |
| 1 aid, 2 months, at $50 | 100.00 |
| 1 aid, 2 months and 26 days, at $40 | 113.55 |
| 1 aid, 9 months and 20 days, at $40 | 386.67 |
| 1 aid, 4 months, at $40 | 160.00 |
| 1 collector, 3 months, at $200 | 600.00 |
| 1 collector, 12 months, at $100 | 1,300.00 |
| 1 collector, 9 months at $80 | 720.00 |
| | 32,410.04 |

| | |
|---|---|
| **Clerical staff:** | |
| 1 chief clerk, 12 months, at $175 | $2,100.00 |
| 1 corresponding clerk, 12 months, at $158.33 | 1,899.96 |
| 1 registrar, 12 months, at $158.33 | 1,899.96 |
| 1 disbursing clerk, 12 months, at $100 | 1,200.00 |
| 1 draftsman, 12 months, at $83.33 | 999.96 |
| 1 assistant draftsman, 12 months, at $40 | 480.00 |
| 1 clerk, 10 months, at $125; 2 months, at $100 | 1,450.00 |
| 1 clerk, 12 months, at $115 | 1,380.00 |
| 1 clerk, 12 months, at $115 | 1,380.00 |
| 1 clerk, 12 months, at $100 | 1,200.00 |
| 1 clerk, 12 months, at $90 | 1,080.00 |
| 1 clerk, 12 months, at $90 | 1,080.00 |
| 1 clerk, 12 months, at $83.33 | 999.96 |
| 1 clerk, 8 months, at $85; 4 months, at $75 | 980.00 |
| 1 clerk, 12 months, at $75 | 900.00 |
| 1 clerk, 12 months, at $70 | 840.00 |
| 1 clerk, 11 months and 18 days, at $60 | 696.00 |
| 1 clerk, 15 days, at $60 | 29.03 |
| 1 clerk, 12 months, at $60 | 720.00 |
| 1 clerk, 12 months, at $60 | 720.00 |
| 1 clerk, 8 months, at $55; 4 months, at $50 | 640.00 |
| 1 clerk, 12 months, at $55 | 660.00 |
| 1 clerk, 11 months and 29 days, at $55 | 658.17 |
| 1 clerk, 12 months, at $50 | 600.00 |
| 1 clerk, 12 months, at $50 | 600.00 |
| 1 stenographer, 10 months and 25 days, at $50 | 540.32 |
| 1 typewriter, 12 months, at $50 | 600.00 |
| 1 typewriter, 11 days, at $60 | 21 29 |
| 1 copyist, 10 months, at $60; 2 months, at $40 | 680.00 |
| 1 copyist, 12 months, at $55 | 660.00 |
| 1 copyist, 12 months, at $50 | 600.00 |
| 1 copyist, 12 months, at $50 | 600.00 |
| 1 copyist, 12 months, at $50 | 600.00 |
| 1 copyist, 12 months, at $50 | 600.00 |
| 1 copyist, 12 months, at $45 | 540.00 |
| 1 copyist, 12 months, at $40 | 480.00 |
| 1 copyist, 12 months, at $40 | 480.00 |
| 1 copyist, 11 months and 16 days, at $40 | 460.65 |
| 1 copyist, 27 days, at $40 | 33.55 |
| 1 copyist, 8 months and 2 days, at $40 | 322.58 |
| 1 copyist, 12 months, at $35 | 420.00 |
| 1 copyist, 12 months, at $35 | 420.00 |
| 1 copyist, 1 month and 33 days, at $30 | 62.52 |
| 1 copyist, 12 months, at $30 | 360.00 |
| 1 copyist, 12 months, at $30 | 360.00 |
| 1 copyist, 1 month, at $30 | 30.00 |
| | 34,063.95 |
| **Preparators:** | |
| 1 artist, 12 months, at $110 | 1,320.00 |
| 1 photographer, 12 months, at $158.33 | 1,899.96 |
| 1 taxidermist, 12 months, at $125 | 1,500.00 |
| 1 taxidermist, 12 months, at $120 | 1,440.00 |
| 1 taxidermist, 12 months, at $80 | 960.00 |

Preparators—Continued.

| | |
|---|---|
| 1 taxidermist, 12 months, at $60 | $720.00 |
| 1 assistant taxidermist, 12 months, at $60 | 720.00 |
| 1 assistant taxidermist, 3 months, at $40 | 120.00 |
| 1 preparator, 11 months, at $100 | 1,100.00 |
| 1 preparator, 12 months, at $80 | 960.00 |
| 1 preparator, 12 months, at $75 | 900.00 |
| 1 preparator, 12 months, at $60 | 720.00 |
| 1 preparator, 32 days, at $50 | 51.62 |
| 1 preparator, 190 days, at $3 | 570.00 |
| 1 preparator, 15 days, at $3.20 | 48.00 |
| 1 assistant preparator, 1 month, at $66; 1 month, at $59; 1 month, at $57.50; 1 month, at $57; 1 month, at $56.50; 1 month, at $55.50; 1 month, at $55; 1 month, at $52; 1 month, at $49; 1 month, at $47.50; 1 month, at $45 1; month, at $44 | 644.00 |
| | 13,673.58 |

Buildings and labor:

| | |
|---|---|
| 1 superintendent of buildings, 12 months, at $137.50 | 1,650.00 |
| 1 assistant superintendent of buildings, 12 months, at $90 | 1,080.00 |
| 1 chief of watch, 12 months, at $60 | 720.00 |
| 1 chief of watch, 12 months, at $60 | 720.00 |
| 1 watchman, 12 months, at $50 | 600.00 |
| 1 watchman, 12 months, at $50 | 600.00 |
| 1 watchman, 12 months, at $50 | 600.00 |
| 1 watchman, 12 months, at $50 | 600.00 |
| 1 watchman, 12 months, at $50 | 600.00 |
| 1 watchman, 12 months, at $50 | 600.00 |
| 1 watchman, 12 months, at $65 | 780.00 |
| 1 watchman, 12 months, at $50 | 600.00 |
| 1 watchman, 12 months, at $50 | 600.00 |
| 1 watchman, 12 months, at $50 | 600.00 |
| 1 watchman, 12 months, at $50 | 600.00 |
| 1 watchman, 12 months, at $50 | 600.00 |
| 1 watchman, 8 months, at $50 | 400.00 |
| 1 watchman, 11 months and 27 days, at $50 | 593.55 |
| 1 watchman, 10 months and 47 days, at $45 | 518.23 |
| 1 watchman, 11 months and 28 days, at $45 | 537.00 |
| 1 watchman, 4 months, at $50; 5 months and 90 days, at $45 | 555.65 |
| 1 watchman, 9 months, at $40 | 360.00 |
| 1 skilled laborer, 12 months, at $50 | 600.00 |
| 1 skilled laborer, 7 months, at $50; 3 months and 52 days, at $40; 10 days, at $2 | 208.26 |
| 1 skilled laborer, 7 months, at $50 | 350.00 |
| 1 skilled laborer, 106 days, at $2 | 212.00 |
| 1 skilled laborer, 5 months, at $45; 27 days, at $1.50 | 265.50 |
| 1 skilled laborer, 4 months, at $45; 2 months, at $46.50; 1 month, at $52.50 | 325.50 |
| 1 skilled laborer, 52 days, at $2 | 104.00 |
| 1 skilled laborer, 2 months, at $45 | 90.00 |
| 1 laborer, 6 months, at $46; 3 months, at $47.50; 3 months, at $43 | 547.50 |
| 1 laborer, 315 days, at $1.50 | 472.50 |
| 1 laborer, 12 months, at $45 | 540.00 |
| 1 laborer, 12 months, at $40 | 480.00 |
| 1 laborer, 11½ days, at $1.50 | 17.25 |

Buildings and labor—Continued.

| | |
|---|---|
| 1 laborer, 3 months, at $44.50; 2 months, at $46; 3 months, at $43; 3 months, at $41.50; 1 month, at $47.50 | $526.50 |
| 1 laborer, 24 days, at $1.50 | 36.00 |
| 1 laborer, 2 months, at $43; 6 months, at $40; 2 months, at $41.50 | 409.00 |
| 1 laborer, 10 months, at $40; 2 months, at $41.50 | 483.00 |
| 1 laborer, 12 months, at $40 | 480.00 |
| 1 laborer, 316 days, at $1.50 | 474.00 |
| 1 laborer, 11 months, at $40; 1 month, at $41.50 | 481.50 |
| 1 laborer, 276 days, at $1.50; 1 month, at $47.50; 1 month, at $48 | 509.50 |
| 1 laborer, 6 months, at $39; 1 month, at $37.50; 2 months, at $40.50; 2 months, at $36; 1 month, at $43.50 | 468.00 |
| 1 laborer, 316 days, at $1.50 | 474.00 |
| 1 laborer, 9 months, at $40; 3 months, at $41.50 | 484.50 |
| 1 laborer, 11 months 16 days, at $40 | 460.64 |
| 1 laborer, 323 days, at $1.50 | 484.50 |
| 1 laborer, 8 months, at $40; 2 months, at $41.50; 1 month, at $38.39 | 401.39 |
| 1 laborer, 261 days, at $1.50 | 391.50 |
| 1 laborer, 27 days, at $1.50 | 40.50 |
| 1 laborer, 20¾ days, at $1.50 | 31.13 |
| 1 laborer, 4 days, at $1.50 | 6.00 |
| 1 laborer, 4 days, at $1.50 | 6.00 |
| 1 laborer, 4 days, at $1.50 | 6.00 |
| 1 laborer, 4 days, at $1.50 | 6.00 |
| 1 laborer, 3 days, at $1.50 | 4.50 |
| 1 attendant, 12 months, at $40 | 480.00 |
| 1 attendant, 12 months, at $40 | 480.00 |
| 1 cleaner, 12 months, at $30 | 360.00 |
| 1 cleaner, 12 months, at $30 | 360.00 |
| 1 cleaner, 12 months, at $30 | 360.00 |
| 1 cleaner, 12 months, at $30 | 360.00 |
| 1 cleaner, 313 days, at $1 | 313.00 |
| 1 cleaner, 300 days, at $1 | 300.00 |
| 1 messenger, 4 months, at $25; 8 months, at $35 | 380.00 |
| 1 messenger, 1 month 36 days, at $20 | 43.65 |
| 1 messenger, 12 months, at $45 | 540.00 |
| 1 messenger, 12 months, at $25 | 300.00 |
| 1 messenger, 12 months, at $25 | 300.00 |
| 1 messenger, 3 months 20 days, at $20 | 72.90 |
| 1 messenger, 12 months, at $35 | 420.00 |
| 1 messenger, 12 months, at $45 | 540.00 |
| 1 messenger, 4 months, at $20; 7 months 30½ days, at $30 | 319.52 |
| 1 messenger, 64 days, at $20 | 41.70 |
| 1 messenger, 8 months 10 days, at $25 | 208.06 |
| 1 messenger, 8 months, at $20 | 160.00 |
| 1 messenger, 14 days, at $20 | 9.03 |
| 1 messenger, 79 days, at $1.25 | 98.75 |
| | 31,837.91 |
| Special services by job or contract | 1,315.28 |
| Total services | 117,300.52 |

SUMMARY.

| | | |
|---|---|---|
| Salaries, preservation of collections, 1891: | | |
| Direction | $3,999.96 | |
| Scientific staff | 32,410.04 | |
| Clerical staff | 34,063.95 | |
| Preparators | 13,673.58 | |
| Buildings and labor | 31,837.71 | |
| Special or contract work | 1,315.28 | |
| Total salaries or compensation | | $117,300.52 |
| Miscellaneous: | | |
| Supplies | 3,052.32 | |
| Stationery | 1,653.02 | |
| Specimens | 6,211.40 | |
| Books and periodicals | 825.40 | |
| Travel | 1,114.78 | |
| Freight and cartage | 1,862.57 | |
| | | 14,719.49 |
| Total expenditure to June 30, 1891, for preservation of collections, 1891 | | 132,020.01 |
| Balance, July 1, 1891, to meet outstanding liabilities | | 7,979.99 |

FURNITURE AND FIXTURES, JULY 1, 1890, TO JUNE 30, 1891.

| | | |
|---|---|---|
| Appropriation by Congress for the fiscal year ending June 30, 1891, "for cases, furniture, fixtures, and appliances required for the exhibition and safe keeping of the collections of the National Museum, including salaries or compensation of all necessary employés" (sundry civil act, August 30, 1890) | | $25,000.00 |
| Salaries or compensation: | | |
| 1 engineer of property, 6 months, at $175; 6 months, at $150 | $1,950.00 | |
| 1 clerk, 12 months, at $75 | 900.00 | |
| 1 copyist, 8 months, at $60; 4 months, at $55 | 700.00 | |
| 1 cabinetmaker, 299 days, at $3 | 897.00 | |
| 1 carpenter, 1 month 10 days, at $91 | 120.35 | |
| 1 carpenter, 313 days, at $3 | 939.00 | |
| 1 carpenter, 313 days, at $3 | 939.00 | |
| 1 carpenter, 313 days, at $3 | 939.00 | |
| 1 carpenter, 307¾ days, at $3 | 923.25 | |
| 1 carpenter, 156½ days, at $3 | 469.50 | |
| 1 carpenter, 183½ days, at $3 | 550.50 | |
| 1 carpenter, 70½ days, at $3 | 211.50 | |
| 1 carpenter, 28 days, at $3 | 84.00 | |
| 1 carpenter, 19 days, at $3 | 57.00 | |
| 1 carpenter, 36 days, at $3 | 108.00 | |
| 1 painter, 12 months, at $65 | 780.00 | |
| 1 skilled laborer, 313 days, at $2 | 626.00 | |
| 1 skilled laborer, 256½ days, at $2 | 513.00 | |
| 1 skilled laborer, 209¼ days, at $2 | 418.50 | |
| 1 skilled laborer, 4 months, at $50 | 200.00 | |
| 1 skilled laborer, 5 months, at $50 | 250.00 | |
| 1 skilled laborer, 3 months, at $45; 1 month, at $46.50; 1 month, at $49.50 | 231.00 | |
| 1 skilled laborer, 8 months, at $45; 1 month, at $48; 1 month, at $46.50 | 454.50 | |

Salaries or compensation—Continued.

| | | |
|---|---|---|
| 1 laborer, 2 months, at $40 | $80.00 | |
| 1 laborer, 2 months, at $40 | 80.00 | |
| 1 laborer, 3 months, at $45; 81 days, at $1.50 | 256.50 | |
| 1 laborer, 302 days, at $1.75 | 528.50 | |
| Special or contract service | 19.00 | |
| Total expenditure for salaries or compensation | | $14,212.52 |

Miscellaneous, materials, etc:

| | | |
|---|---|---|
| Exhibition cases | 1,295.00 | |
| Designs and drawings for cases | 36.00 | |
| Drawers, trays, boxes | 448.08 | |
| Frames, stands, etc | 330.52 | |
| Glass | 954.56 | |
| Hardware and fittings for cases | 707.13 | |
| Tools | 73.67 | |
| Cloth, cotton, etc | 108.03 | |
| Glass jars | 61.92 | |
| Lumber | 1,364.05 | |
| Paints, oils, and brushes | 565.40 | |
| Office furniture | 588.22 | |
| Tin, lead, and metals | 268.48 | |
| Rubber goods | 105.04 | |
| Iron brackets | 87.10 | |
| Apparatus | 84.50 | |
| Travelling expenses | 5.00 | |
| Plumbing | 14.24 | |
| | | 7,096.94 |
| Total expenditure, July 1, 1890, to June 30, 1891, for furniture and fixtures, 1891 | | 21,309.46 |
| Balance, July 1, 1891, to meet outstanding liabilities | | 3,690.54 |

HEATING, LIGHTING, ELECTRIC AND TELEPHONIC SERVICE, JULY 1, 1890, TO JUNE 30, 1891.

Appropriation by Congress for the fiscal year ending June 30, 1891, "for expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum" (sundry civil act, August 30, 1890) .... $12,000.00

Salaries or compensation:

| | |
|---|---|
| 1 engineer, 7 months, at $115 | $805.00 |
| 1 fireman, 12 months, at $50 | 600.00 |
| 1 fireman, 12 months, at $50 | 600.00 |
| 1 fireman, 10 months, 59½ days, at $50 | 597.56 |
| 1 fireman, 9 months 5 days, at $50 | 458.33 |
| 1 fireman, 8 months 15 days, at $50 | 424.19 |
| 1 fireman, 1 month 14 days, at $50 | 72.58 |
| 1 telephone clerk, 12 months, at $60 | 720.00 |
| 1 assistant telephone clerk, 12 months, at $35 | 420.00 |
| 1 laborer, 226 days, at $1.50 | 339.00 |
| Special-service contract | 48.25 |
| Expenditure for salaries | 5,084.91 |

| | | | |
|---|---|---|---|
| General expenses: | | | |
| Coal and wood | $2,766.96 | | |
| Gas | 1,233.84 | | |
| Telephones | 604.40 | | |
| Electric work | 7.50 | | |
| Electric supplies | 905.68 | | |
| Rental of call boxes | 100.00 | | |
| Heating repairs and work, heating supplies | 448.95 | | |
| Travel | 5.42 | | |
| | | $6,072.75 | |
| Total expenditures, July 1, 1890, to June 30, 1891, for heating, lighting, etc | | | $11,157.66 |
| Balance, July 1, 1891, to meet outstanding liabilities | | | 842.34 |

POSTAGE, JULY 1, 1890, TO JUNE 30, 1891.

| | |
|---|---|
| Appropriation by Congress for the fiscal year ending June 30, 1891, "for postage stamps and foreign postal cards for the National Museum" (sundry civil act, August 30, 1890) | $500.00 |
| City post-office, for postage and postal cards | 500.00 |
| Appropriation all expended July 1, 1891. | |

PRINTING, JULY 1, 1890, TO JUNE 30, 1891.

| | | |
|---|---|---|
| Appropriation by Congress for the fiscal year ending June 30, 1891, "for printing labels and blanks for the use of the National Museum, and for 'Bulletins' and annual volumes of the 'Proceedings' of the National Museum | | 10,000.00 |
| Bulletins Nos. 36, 38, 39; Special Bulletin No. 1 | $1,100.27 | |
| Proceedings, Vols. XII, XIII, XIV | 3,398.56 | |
| Extras from reports | 783.46 | |
| Circulars | 3.93 | |
| Labels for specimens | 2,438.81 | |
| Letter heads, memorandum pads, and envelopes | 170.21 | |
| Blanks | 682.26 | |
| Catalogue cards | 337.85 | |
| Congressional Records | 20.00 | |
| Total expenditure, July 1, 1890, to June 30, 1891, for printing, National Museum | | 8,935.35 |
| Balance July 1, 1891 | | 1,064.65 |

PERKINS COLLECTION OF PREHISTORIC COPPER IMPLEMENTS.

| | |
|---|---|
| Appropriation by Congress "to enable the Secretary of the Smithsonian Institution to purchase from Frederic S. Perkins, of Wisconsin, his collection of prehistoric copper implements" (deficiency act, September 30, 1890) | 7,000.00 |
| F. S. Perkins, collection of prehistoric copper implements | 7,000.00 |
| (Paid direct by Treasury Department to F. S. Perkins.) | |

PAYMENT TO DAUGHTERS OF THE LATE JOSEPH HENRY, SECRETARY OF THE SMITHSONIAN INSTITUTION.

| | |
|---|---|
| Appropriation by Congress "for payments to the daughters of the late Joseph Henry, Secretary of the Smithsonian Institution, for valuable public services rendered by him" (sundry civil act, March 3, 1891) | 10,000.00 |
| Payment of above direct by Treasury Department to Mary, Helen, and Caroline Henry, daughters of Prof. Joseph Henry | 10,000.00 |

PURCHASE OF THE CAPRON COLLECTION OF JAPANESE WORKS OF ART.

| | |
|---|---|
| Appropriation by Congress "for the purchase of 'the Capron collection of Japanese works of art,' now on temporary deposit in the National Museum, at Washington, District of Columbia" (sundry civil act, March 3, 1891) | $10,000.00 |
| Payment of above direct to the heirs of Horace Capron by the Treasury Department | 10,000.00 |

## OTHER MUSEUM APPROPRIATIONS.

PRESERVATION OF COLLECTIONS, 1888–'89.

| | | |
|---|---|---|
| Balance, July 1, 1890, as per last annual report | | $15.18 |
| Expenditures from July 1, 1890, to July 1, 1891: | | |
| Supplies | $13.00 | |
| Freight | 2.15 | |
| | | 15.15 |
| Balance July 1, 1891 | | .03 |

Carried, under the action of Revised Statutes, section 3090, by the Treasury Department, to the credit of the surplus fund, June 30, 1891:

PRESERVATION OF COLLECTIONS, 1890.

| | | | |
|---|---|---|---|
| Balance, July 1, 1890, as per last annual report | | | $3,848.76 |
| Expenditures from July 1, 1890, to July 1, 1891: | | | |
| 1 curator, 1 month | $100.00 | | |
| 1 collector, 4 months, at $200 | 800.00 | | |
| 1 copyist, 8 days, at $1.50 | 12.00 | | |
| Special-contract work | 634.78 | | |
| | | $1,546.78 | |
| Supplies | | 317.90 | |
| Stationery | | 75.79 | |
| Specimens | | 1,132.50 | |
| Travel | | 326.39 | |
| Freight | | 244.27 | |
| Books | | 190.21 | |
| Expenditure to July 1, 1891 | | | 3,833.84 |
| Balance, July 1, 1891 | | | 14.92 |

*Statement of total expenditures of the appropriation for preservation of collections, 1890.*

| | Expenditures. | | |
|---|---|---|---|
| | From July 1, 1889, to June 30, 1890. | From July 1, 1890, to June 30, 1891. | Total to June 30, 1891. |
| For salaries | $118,378.99 | $1,546.78 | $119,925.77 |
| Supplies | 4,952.67 | 317.90 | 5,270.57 |
| Stationery | 2,307.60 | 75.79 | 2,383.39 |
| Specimens | 5,141.48 | 1,132.50 | 6,273.98 |
| Travel | *1,646.42 | 326.39 | 1,972.36 |
| Freight | 2,416.92 | 244.27 | 2,661.19 |
| Books | 1,307.61 | 190.21 | 1,497.82 |
| Total | 136,151.69 | 3,833.84 | 139,985.08 |

* Disallowance, 45 cents.

*Furniture and fixtures, 1889.*

Balance as per last annual report .......................................... $0.40

Carried under the action of Revised Statutes, section 3090, by the Treasury Department, to the credit of the surplus fund, June 30, 1891.

*Furniture and fixtures, 1890.*

| | | |
|---|---|---|
| Balance July 1, 1890, as per last annual report | | $1,192.41 |
| Expenditures from July 1, 1890, to June 30, 1891: | | |
| Special services | $10.00 | |
| Designs and drawings for cases | 40.75 | |
| Frames, stands, etc | 11.60 | |
| Glass | 105.32 | |
| Hardware | 353.22 | |
| Tools | 4.70 | |
| Lumber | 183.21 | |
| Paints | 43.55 | |
| Office furniture | 63.17 | |
| Tin, lead, etc | 12.50 | |
| Rubber goods | 19.41 | |
| Apparatus | 339.75 | |
| Travelling expenses | 4.95 | |
| Total expenditure | | 1,192.13 |
| Balance July 1, 1891 | | .28 |

*Statement of total expenditures of appropriation for furniture and fixtures, 1890.*

| | From July 1, 1889, to June 30, 1890. | From July 1, 1890, to June 30, 1891. | Total to June 30, 1891. |
|---|---|---|---|
| Salaries | $15,926.21 | $10.00 | $15,936.21 |
| Exhibition cases | 4,366.77 | .............. | 4,366.77 |
| Designs and drawings for cases | 57.00 | 40.75 | 97.75 |
| Drawers, trays, and boxes | 931.48 | .............. | 931.48 |
| Frames, stands, etc | 158.84 | 11.60 | 170.44 |
| Glass | 1,875.38 | 105.32 | 1,980.70 |
| Hardware | 1,291.07 | 353.22 | 1,644.29 |
| Tools | 107.37 | 4.70 | 112.07 |
| Cloth, cotton, etc | 85.97 | .............. | 85.97 |
| Glass jars | 395.45 | .............. | 395.45 |
| Lumber | 1,276.88 | 183.21 | 1,460.09 |
| Paints, oil, and brushes | 681.68 | 43.55 | 725.23 |
| Office furniture | 605.19 | 63.17 | 668.36 |
| Chairs for halls | 51.00 | .............. | 51.00 |
| Tin, lead, etc | 90.98 | 12.50 | 103.48 |
| Brick and plaster | 98.00 | .............. | 98.00 |
| Rubber goods | 40.87 | 19.41 | 60.28 |
| Iron brackets | 130.00 | .............. | 130.00 |
| Apparatus | 605.50 | 339.75 | 945.25 |
| Travelling expenses | 31.95 | 4.95 | 36.90 |
| Total | 28,807.59 | 1,192.13 | 29,999.72 |

*Heating, lighting, etc., 1889.*

Balance as per last annual report .......................................... $3.99

Carried under the action of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1891.

*Heating, lighting, etc., 1890.*

| | | |
|---|---|---|
| Balance July 1, 1890, as per last report | | $2,327.15 |
| Expenditures from July 1, 1890, to June 30, 1891: | | |
| For gas | $74.50 | |
| For telephones | 201.00 | |
| For electric work | 60.00 | |
| For electric supplies | 1,962.00 | |
| For rental of call-boxes | 20.00 | |
| For heating supplies | 7.80 | |
| Total expenditures | | 2,325.30 |
| Balance July 1, 1891 | | 1.85 |

*Statement of total expenditures of appropriation for heating, lighting, etc., 1890.*

| | From July 1, 1889, to June 30, 1890. | From July 1, 1890, to June 30, 1891. | Total to June 30, 1891. |
|---|---|---|---|
| Salaries | $5,114.87 | | $5,114.87 |
| Coal and wood | 2,058.26 | | 2,058.26 |
| Gas | *1,113.82 | $74.50 | 1,188.32 |
| Telephones | 601.05 | 201.00 | 802.05 |
| Electric work | 154.40 | 60.00 | 214.40 |
| Electric supplies | 110.09 | 1,962.00 | 2,072.09 |
| Rental of call-boxes | 100.00 | 20.00 | 120.00 |
| Heating repairs | 269.25 | | 269.25 |
| Heating supplies | 147.86 | 7.80 | 155.66 |
| Travelling expenses | 3.25 | | 3.25 |
| Total | 9,672.85 | 2,325.30 | 11,998.15 |

*National Museum—Printing, 1890.*

| | |
|---|---|
| Balance July 1, 1890 | $64.55 |

Remaining in United States Treasury.

NATIONAL ZOÖLOGICAL PARK.

*Organization, improvement, and maintenance.*

| | | |
|---|---|---|
| Balance July 1, 1890 | | $91,081.50 |
| Expenditures from July 1, 1890, to June 30, 1891: | | |
| Shelter of animals | $13,631.42 | |
| Shelter, barns, cages, fences, etc | 8,613.33 | |
| Repairs to Holt mansion, etc | 2,000.00 | |
| Artificial ponds, etc | 56.16 | |
| Water supply, sewers, and drainage | 657.14 | |
| Roads, walks, and bridges | 10,244.19 | |
| Miscellaneous supplies | 3,974.90 | |
| Current expenses | 28,432.52 | |
| | | 67,639.66 |
| Balance July 1, 1891 | | 23,441.84 |

*Statement of the total expenditures of the appropriation for the National Zoölogical Park, act of April 30, 1890.*

| | From April 30, 1890, to June 30, 1890. | From July 1, 1890, to June 30, 1891. | Total to June 30, 1891. |
|---|---|---|---|
| Shelter of animals | $43.83 | $13,631.42 | $13,675.25 |
| Shelter, barns, cages, fences, etc | | 8,643.33 | 8,643.33 |
| Repairs to Holt mansion, etc | | 2,000.00 | 2,000.00 |
| Artificial ponds, etc | | 56.16 | 56.16 |
| Water supply, sewerage and drainage | | 657.14 | 657.14 |
| Roads, walks, and bridges | | 10,244.19 | 10,244.19 |
| Miscellaneous supplies | 157.57 | 3,974.90 | 4,132.47 |
| Current expenses | 717.10 | 28,432.52 | 29,149.62 |
| Total | 918.50 | 67,639.66 | 68,558.16 |

*Smithsonian Institution building repairs.*

| | | |
|---|---|---|
| Appropriation by Congress "for fire-proofing the so-called chapel of the west wing of the Smithsonian Institution building, and for repairing the roof of the main building, and the ceiling and plastering of the main hall of the building, said work to be done under the supervision of the Architect of the Capitol, with the approval of the Regents of the Smithsonian Institution, and no portion of the appropriation to be used for skylights in the roof nor for well-hole in the floor of the main building (sundry civil act, August 30, 1890) | | $25,000.00 |
| Expenditures from August 30, 1890, to June 30, 1891: | | |
| Advertising | $12.78 | |
| Iron roof and ceiling (contract) | 1,620.00 | |
| Labor | 354.86 | |
| Lumber | 368.94 | |
| Roofing materials | 41.90 | |
| Stationery, printing, etc | 5.50 | |
| Travelling expenses | 10.25 | |
| | | 2,414.23 |
| Balance July 1, 1891 | | 22,585.77 |

*International exchanges, 1888–1889.*

| | |
|---|---|
| Balance July 1, 1889 | 21.80 |
| Expenditures from July 1, 1889, to June 30, 1891: | |
| Freight | 21.47 |
| Balance June 30, 1891 | .33 |

Carried under the action of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1891.

*International exchanges, 1889–1890.*

| | | |
|---|---|---|
| Balance July 1, 1890 | | $11.99 |
| Expenditures from July 1, 1890, to June 30, 1891: | | |
| Freight | $11.45 | |
| Stationery and supplies | 54 | |
| | | 11.99 |

## RECAPITULATION.

The total amount of funds administered by the Institution during the year ending June 30, 1891, appears from the foregoing statements and the account books to have been as follows:

### SMITHSONIAN INSTITUTION.

| | | |
|---|---|---|
| From balance of last year, July 1, 1890 (including cash from executors of Dr. J. H. Kidder, $5,000; including cash from gift of Dr. Alex. G. Bell, $5,000) | $30,192.65 | |
| From interest on Smithsonian fund for the year | 42,180.00 | |
| From sales of publications | 418.36 | |
| From repayments for freights, etc | 6,344.01 | |
| Total | | $79,135.02 |

### APPROPRIATIONS COMMITTED BY CONGRESS TO THE CARE OF THE INSTITUTION.

| | | |
|---|---|---|
| International exchanges: | | |
| From balance of year 1888-'89 | $21.80 | |
| From balance of last year, July 1, 1889-'90 | 11.99 | |
| From appropriation for 1890-'91 | 17,000.00 | |
| Total | | $17,033.79 |
| North American Ethnology: | | |
| From balance of last year (1889-'90), July 1, 1890 | 12,033.08 | |
| From appropriation for 1890-'91 | 40,000.00 | |
| Total | | 52,033.08 |
| Preservation of collections—Museum: | | |
| From balance of 1888-'89 | 15.18 | |
| From balance of 1889-'90, July 1, 1890 | 3,846.76 | |
| From appropriation for 1890-'91 | 140,000.00 | |
| Total | | 143,863.94 |
| Printing—Museum: | | |
| From balance of July, 1889-'90, July 1, 1890 | 64.55 | |
| From appropriation of 1890-'91 | 10,000.00 | |
| Total | | 10,064.55 |
| Perkin's collection of prehistoric copper implements: | | |
| From appropriation for 1890-'91 | 7,000.00 | |
| Total | | 7,000.00 |
| Furniture and fixtures—Museum: | | |
| From balance of 1889-'90, July 1, 1890 | 1,192.41 | |
| From appropriation for 1890-'91 | 25,000.00 | |
| Total | | 26,192.41 |
| Heating, lighting, etc.—Museum: | | |
| From balance of 1888-'89 | 3.99 | |
| From balance of 1889-'90, July 1, 1890 | 2,327.15 | |
| From appropriation for 1890-'91 | 12,000.00 | |
| Total | | 14,331.14 |
| Postage—Museum: | | |
| From balance of 1889-'90, July 1, 1890 | 500.00 | |
| From appropriation for 1890-'91 | 500.00 | |
| Total | | 1,000.00 |

| | | |
|---|---|---|
| National Zoölogical Park: | | |
| From balance of 1889-'90, July 1, 1890 | $91,081.50 | |
| From appropriation for 1890-'91 | 50,500.00 | |
| Total | | $141,581.50 |
| Smithsonian Institution—Building repairs: | | |
| From appropriation for 1890-'91 | 25,000.00 | |
| Total | | 25,000.00 |
| Daughters of the late Joseph Henry, secretary of the Smithsonian Institution: | | |
| From appropriation March 3, 1891 | | 10,000.00 |
| Purchase of the Capron collection of Japanese works of art: | | |
| From appropriation March 3, 1891 | | 10,000.00 |

SUMMARY.

| | |
|---|---|
| Smithsonian Institution | $79,135.02 |
| Exchanges | 17,033.79 |
| Ethnology | 52,023.08 |
| Preservation of collections | 143,863.94 |
| Furniture and fixtures | 26,192.41 |
| Heating and lighting | 14,331.14 |
| Postage | 1,000.00 |
| Printing | 10,064.55 |
| Perkins collection | 7,000.00 |
| Zoölogical park | 141,581.50 |
| Smithsonian building repairs | 25,000.00 |
| Daughters of Joseph Henry | 10,000.00 |
| Capron collection | 10,000.00 |
| | 537,235.43 |

The committee has examined the vouchers for payments made from the Smithsonian income during the year ending June 30, 1891, all of which bear the approval of the Secretary of the Institution, or, in his absence, of the Assistant Secretary as Acting Secretary, and a certificate that the materials and services charged were applied to the purposes of the institution.

The committee has also examined the accounts of the "International Exchanges," and of the "National Museum," and of the "National Zoölogical Park," and finds that the balances above given correspond with the certificates of the disbursing clerk of the Smithsonian Institution, whose appointment as such disbursing officer was accepted and his bonds approved by the Secretary of the Treasury.

The quarterly accounts-current, the vouchers, and journals have been examined and found correct.

At the last session of Congress a change was made in the phraseology of the appropriation made for ethnological researches (or the Bureau of Ethnology). Heretofore the appropriation was placed under the direction of the "Secretary of the Smithsonian Institution," and the Executive Committee decided that it was not their province to examine the vouchers, although the abstracts of expenditures and balance-sheets were exhibited to them quarterly. The expenditures were made by the

disbursing clerk of the Bureau of Ethnology, a bonded officer approved as such by the Treasury Department, and had the approval of Maj. Powell, the Director of the Bureau, and also of the Secretary of the Institution.

The appropriation for 1890-'91 has been placed by Congress "under the direction of the Smithsonian Institution," and the committee decided that the accounts and vouchers should be examined by them in the same manner as other expenditures for which the Regents of the Institution are in any degree responsible.

The disbursement of the balance of last year's appropriation has continued in the hands of the disbursing clerk of the Bureau (Mr. J. D. McChesney), but those of the new appropriation will be made by the disbursing clerk of the Smithsonian Institution (Mr. W. W. Karr), accepted as a bonded officer by the Secretary of the Treasury.

*Statement of regular income from the Smithsonian fund available for use in the year ending June 30, 1892.*

| | | |
|---|---|---|
| Balance on hand June 30, 1891 (including the cash from executors of Dr. J. H. Kidder, $5,000; including the cash from Alex. Graham Bell, $5,000) | | $40,062.11 |
| Interest due and receivable July 1, 1891 | $21,090.00 | |
| Interest due and receivable January 1, 1892 | 21,090.00 | |
| | | 42,180.00 |
| Total available for year ending June 30, 1892 | | 82,242.11 |

Respectfully submitted.

JAMES C. WELLING,
HENRY COPPÉE,
M. O. MEIGS,
*Executive Committee.*

WASHINGTON, D. C., *October, 1891.*

# ACTS AND RESOLUTIONS OF CONGRESS RELATIVE TO THE SMITHSONIAN INSTITUTION, NATIONAL MUSEUM, ETC.

(In continuation from previous reports.)

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[Fifty-first Congress, second session, 1890-'91.]

SMITHSONIAN INSTITUTION:—INTERNATIONAL EXCHANGES.

For expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, seventeen thousand dollars. (Sundry civil appropriation act, approved March 3, 1891.)

*U. S. Geological Survey:* For the purchase of necessary books for the library and the payment for the transmission of public documents through the Smithsonian exchange, two thousand five hundred dollars. (Sundry civil appropriation act, approved March 3, 1891.)

*War Department:* For the transportation of reports and maps to foreign countries through the Smithsonian Institution, one hundred dollars. (Sundry civil appropriation act, approved March 3, 1891.)

To pay the Chicago, Rock Island and Pacific Railroad Company amount found due by the accounting officers of the Treasury on account of international exchanges, Smithsonian Institution, being for the service of the fiscal year eighteen hundred and eighty-nine, sixty-six cents. (Deficiency act, Ch. 540, Statutes, p. 866. Approved March 3, 1891.)

*Library of Congress:* For expenses of exchanging public documents for the publications of foreign governments, one thousand five hundred dollars. (Legislative, executive, and judicial act, Ch. 541, Statutes, page 914. Approved March 3, 1891.)

*Naval Observatory:* For repairs [etc., etc.], * * * including payment to Smithsonian Institution for freight on observatory publications sent to foreign countries, postage, expressage [etc., etc.], four thousand five hundred and fifty dollars. (Legislative, executive, and judicial act, Ch. 541, Statutes, p. 935. Approved March 3, 1891.)

*United States Patent Office:* For purchase of books, and expenses of transporting publications, patents issued by the Patent Office to foreign governments, three thousand dollars. (Legislative, executive, and judicial act, Ch. 541, Statutes, p. 939. Approved Mar. 3, 1891.)

## U. S. NATIONAL MUSEUM.

For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources including salaries or compensation of all necessary employees, one hundred and forty-five thousand dollars.

For cases, furniture, fixtures, and appliances required for the exhibition and safe keeping of the collections of the National Museum, including salaries or compensation of all necessary employees, twenty-five thousand dollars.

For expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum, twelve thousand dollars.

For removing old boilers under Museum hall in Smithsonian Building, replacing them with new ones, and for necessary alterations, and connections of steam heating apparatus and for covering pipes with fireproof material, three thousand dollars.

For removing the decayed wooden floors in the Museum building, substituting granolithic or artificial stone therefor, and for slate for covering trenches containing heating and electric apparatus, including all necessary material and labor, to be immediately available, five thousand dollars.

For the purchase of "the Capron collection of Japanese works of art," now on temporary deposit in the National Museum at Washington, District of Columbia, ten thousand dollars.

For postage stamps and foreign postal cards for the National Museum, five hundred dollars.

For payment to the daughters of the late Joseph Henry, Secretary of the Smithsonian Institution, for valuable public services rendered by him, ten thousand dollars. (Sundry civil appropriation act, approved Mar. 3, 1891.)

*Public Printer:* For the Smithsonian Institution for printing for the use of the National Museum not exceeding one thousand dollars. (Deficiency act, Ch. 540, Statutes, p. 887. Approved March 3, 1891.)

*Public Printing and Binding:* For the Smithsonian Institution for printing labels and blanks and for the "Bulletins" and annual volumes of the "Proceedings" of the National Museum, fifteen thousand dollars. (Sundry civil appropriation act, approved March 3, 1891.)

To meet customs duties on glass, tin, and other dutiable articles and supplies imported for the United States National Museum, one thousand dollars. (Deficiency act, Ch. 540, Statutes, p. 866. Approved March 3, 1891.)

## NORTH AMERICAN ETHNOLOGY.

For continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, fifty thousand dollars. (Sundry civil appropriation act, approved March 3, 1891.)

## NATIONAL ZOOLOGICAL PARK.

For continuing the construction of roads, walks, bridges, water supply, sewerage, and drainage, and for grading, planting, and otherwise improving the grounds of the National Zoological Park, including salaries or compensation of all necessary employees, fifteen thousand dollars.

For erecting and repairing buildings and inclosures for animals and for administrative purposes, in the national Zoological Park, including salaries or compensation of all necessary employees, eighteen thousand dollars;

For care, subsistence, and transportation of animals for the National Zoological Park, and for the *purpose* [purchase] of rare specimens not otherwise obtainable, including salaries or compensation of all necessary employees, and general incidental expenses not otherwise provided for, seventeen thousand five hundred dollars; in all, fifty thousand five hundred dollars, one-half of which sum shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States. (Sundry civil appropriation act, approved March 3, 1891).

### ASTRO-PHYSICAL OBSERVATORY

For maintenance of astro-physical observatory, under the direction of the Smithsonian Institution, including salaries of assistants and the purchase of additional apparatus, ten thousand dollars. (Sundry civil appropriation act, approved March 3, 1891.)

### WORLD'S COLUMBIAN EXPOSITION.

GOVERNMENT EXHIBIT. For the selection, purchase, preparation, and arrangement of such articles and materials as the heads of the several Executive Departments, the Smithsonian Institution and National Museum, and the United States Fish Commission may decide shall be embraced in the Government exhibit, and such additional articles as the President may designate for said Exposition, and for the employment of proper persons as officers and assistants to the Board of Control and Management of the Government exhibit, appointed by the President, of which not exceeding five thousand dollars may be expended by the said board for clerical services, the sum of three hundred and fifty thousand dollars is hereby appropriated for the service of the fiscal year ending June thirtieth, eighteen hundred and ninety-two, and any moneys heretofore appropriated in aid of said Government exhibit may be used in like manner and for like purposes: *Provided*, That all expenditures made for the purposes and from the appropriation herein specified shall be subject to the approval of the said Board of Control and Management and of the Secretary of the Treasury, as now provided by law.

WORLD'S COLUMBIAN COMMISSION. For the World's Columbian Commission, ninety-five thousand five hundred dollars, of which sum thirty-six thousand dollars shall be used for the Board of Lady Managers.

For expenses connected with the admission of foreign goods to the Exposition, as set forth in section twelve of the act creating the Commission, approved April twenty-fifth, eighteen hundred and ninety, twenty thousand dollars;

For contingent expenses of the World's Congress Auxiliary of the World's Columbian Exposition, two thousand five hundred dollars.

And the several sums herein appropriated for the World's Columbian Exposition shall be deemed a part of the sum of one million five hundred thousand dollars, the limit of liability of the United States on account thereof fixed by the act of April twenty-fifth, eighteen hundred and ninety, authorizing said Exposition. (Sundry civil appropriation act, approved March 3, 1891.)

# REPORT OF S. P. LANGLEY,

## SECRETARY OF THE SMITHSONIAN INSTITUTION,

### FOR THE YEAR ENDING JUNE 30, 1891.

*To the Board of Regents of the Smithsonian Institution:*

GENTLEMEN: I have the honor to submit herewith my report for the year ending June 30, 1891, of the operations of the Smithsonian Institution, including the work placed by Congress under its charge in the National Museum, the Bureau of Ethnology, the International Exchanges, the National Zoölogical Park, and the Astro-physical Observatory.

I have spoken personally and briefly of matters of chief importance concerning these various Bureaus, and have then added, for the sake of completeness, detailed reports from the Bureau of Ethnology, the International Exchange Bureau, the Library, the National Zoölogical Park, and the Editor in charge of Publications, which are contained in the Appendix. The work of the National Museum is reported on at length in a separate volume by the Assistant Secretary in charge.

## THE SMITHSONIAN INSTITUTION.

### THE ESTABLISHMENT.

I have to record a change in the establishment during the year, in the death of the Hon. William Windom, Secretary of the Treasury, on 29th January, 1891, and the appointment of his successor to the Secretaryship, the Hon. Charles Foster.

### THE BOARD OF REGENTS.

In accordance with a resolution of the Board of Regents fixing the time of the stated annual meeting of the Board on the 4th Wednesday of January in each year, the Board met on January 28, 1891, at 10 o'clock a. m.

The Hon. Charles Devens, of Massachusetts, whose appointment as a member of the Board by joint resolution of Congress on May 22, 1890, was noted in the report for last year, formally declined the appointment on account of a provision in the constitution of the State of Massachu-

setts whereby justices of the supreme judicial court of the Commonwealth are rendered incapable of holding any place or office from any other State, Government, or power whatever. I regret to add that Judge Devens died on the 7th of January, 1891.

The vacancy in the Board has not yet been filled.

The Hon. George Bancroft and Gen. William T. Sherman have died during the year. The lives of these two eminent men have made their loss a national one, so widely known, and accompanied by obituary notices so general and so complete, that to repeat them here would be a work of superfluity. Reference is made to them elsewhere in the necrologic notices only so far as relates to their connection with the Board of Regents.

Mr. Justice Miller, whose death occurred on the 16th of November, 1890, is also to be mentioned here, having been, as acting Chief Justice, elected temporarily Chancellor of the Board. He served in this capacity from March 27, 1888, to January 9, 1889. It would be superfluous, as in the former cases, to do more than to note the fact and with it to recall the sincerity of the respect and the warmth of the regard which all felt for him who knew him in this or in any other capacity of his eminent official life.

### ADMINISTRATION.

I wish again to remark that the great extension of the interests confided to the Institution make the duties of the Secretary and his assistants altogether different from what they were in its early history. The change brought about by constant growth of its activities has been so uniform in its progression that there has been no particular moment at which it seemed possible to say that the burden of the work had grown to transcend wholly the means for effecting it. At present I feel confident that I am justified in saying that such is the case, and that some provision must now be made for enabling the Secretary and his immediate assistants to have additional aid in this administration of the affairs of the General Government from some source not provided for out of the already insufficient funds of the parent institution.

This institution administers large Government interests, while no appropriation has been made by Congress for the expense of such administration, such as is made in all other analogous cases, and this expense is directly represented by an increment of the expenditure of the parent institution, chiefly under the head of salaries, which are not needed for the purposes of the original fund alone.

### FINANCES.

I have in a previous report referred to the fact that owing to the changing value of money, the purchasing power of the Smithsonian fund, in the language of a committee of the Regents—

"while nominally fixed, is growing actually less year by year, and of less and less importance in the work it accomplishes with reference to

the immense extension of the country since the Government accepted the trust;"

so that it seems most desirable that the fund should be enlarged, if only to represent the original position of its finances relatively to those of the country and institutions of learning.

Everything which has occurred since this was written increases the force of the observation. I only remark upon it here to say that I have taken some pains to invite the attention of those who are seeking a trustee for the disposition of means intended for the advancement of knowledge, to the especial guaranties for security offered by the administration of the Regents.

It is proper to mention, in this connection, that I have during the past year come into communication with a gentleman who desires to donate $200,000 to the fund, provided he can do so on certain conditions, with regard to which I have not felt myself authorized to act without consulting the Regents, and as, nevertheless, they can not be assembled during the present year, I have taken the unusual step, justified by the occasion, of telegraphing to each individual member of the body to ask his opinion.

Favorable opinions have been received in answer to this from nearly all the Regents and I may anticipate a statement properly belonging to a later report when I say that the sum in question has since been placed in my hands by the donor, Mr. Thomas G. Hodgkins, of Setauket, Long Island, to be tendered to the Regents at their next meeting.

The invested funds of the Institution are as follows, being in the same condition as in my last report:

| | |
|---|---|
| Bequest of Smithson, 1846 | $515,169.00 |
| Residuary legacy of Smithson, 1867 | 26,210.63 |
| Deposits from savings of income, etc., 1867 | 108,620.37 |
| Bequest of James Hamilton, 1874 | 1,000.00 |
| Bequest of Simeon Habel, 1880 | 500.00 |
| Deposits from proceeds of sale of bonds, 1881 | 51,500.00 |
| Total permanent Smithsonian fund in the Treasury of the United States, bearing interest at 6 per cent per annum | 703,000.00 |

At the beginning of the fiscal year the balance on hand was $30,192.65. Interest on the invested fund, amounting to $42,180, has been received from the Treasurer of the United States during the year, and from sales of publications and miscellaneous sources, including repayments on account of international exchanges, $6,762.37, making a total of $79,135.02.

The total expenditures, as shown in detail in the report of the executive committee, have been $39,072.91, leaving an unexpended balance on June 30, 1891, of $40,062.11. This includes a sum of $10,000, the amount of a bequest of $5,000 from the late Dr. J. H. Kidder and a donation of a like amount from Dr. Alexander Graham Bell personally to the Secretary for physical investigations, which was, with the donor's consent, deposited by the Secretary to the credit of the funds of the Institution subject to order. Neither of these sums, then, forms a portion

of the invested funds, and both have been held in the hope that Congress would later provide a site for a permanent building for the astrophysical observatory. The balance then available for the general purposes of the Institution on July 1, 1891, was $30,062.11, but this is in part held against various liabilities for scientific purposes.

The Institution has been charged by Congress with the disbursements during the year of the following appropriations:

| | | |
|---|---|---|
| For international exchanges | | $17,000 |
| For ethnological researches | | 40,000 |
| For National Museum: | | |
| Preservation of collections | $140,000 | |
| Furniture and fixtures | 25,000 | |
| Heating and lighting | 12,000 | |
| Postage | 500 | |
| Printing | 10,000 | |
| Perkin's collection prehistoric copper implements | 7,000 | |
| For Smithsonian Institution Building repairs | | 25,000 |

To these should be added the unexpended balance of the special appropriation of $92,000 made April 30, 1890, for the National Zoological Park.

The vouchers for the disbursement of these appropriations have been examined by the executive committee, and the various items of expenditure are set forth in a letter addressed to the Speaker of the House of Representatives in accordance with a provision of the sundry civil act of October 2, 1888, while the expenditures from the Smithsonian fund have likewise been examined and approved by the executive committee and are shown in their report.

I may here call attention to a change in the phraseology of the sundry civil act making appropriation for ethnological researches, whereby the appropriation is placed "under the direction of the Smithsonian Institution," instead of in the charge of the "Secretary of the Smithsonian Institution," as heretofore. The vouchers from the Bureau of Ethnology are therefore now scrutinized by the executive committee, as are all other expenditures of the Institution.

The estimates for the fiscal year ending June 30, 1892, forwarded to the Secretary of the Treasury under date of October 20, 1890, were as follows:

| | |
|---|---|
| International exchanges | $32,400 |
| North American ethnology | 50,000 |
| National Museum: | |
| Preservation of collections | 180,000 |
| Heating and lighting | 15,000 |
| Furniture and fixtures | 30,000 |
| Printing and binding | 19,000 |
| Postage | 1,000 |
| Customs duties on glass, tin, etc | 3,000 |
| Replacing old boilers, etc | 3,000 |
| Replacing wooden floor with granolithic or artificial stone | 5,000 |
| National Zoological Park | 101,350 |
| Astrophysical observatory | 10,000 |

BUILDINGS.

I must again urge upon the attention of the Regents the ever-increasing necessity for relief from the overcrowded condition of the National Museum. The lack of more adequate accommodation has been even more forcibly presented than ever before in making the necessary preparations for the Museum exhibit at the World's Columbian Exposition in Chicago.

The present Museum building was finished and occupied in 1881. The collections increased so rapidly that as early as 1883 the Regents, at their meeting of January 17, recommended to Congress the erection of a new building.

Since 1883 the collections have again increased to such an extent that a new building as large as the present one could now be practically filled with material held in storage, and I can only repeat with increased emphasis the closing sentence of my letter of January 21, 1890, to the Hon. Leland Stanford, Chairman of the Senate Committee on Public Buildings and Grounds, "that unless more space is provided the development of the Government collection, which is already partly arrested, will be almost completely stopped."

Plans for a new museum building of two stories and basement were laid before the Board in January, 1890, and on February 19, 1890, a bill appropriating $500,000 was reported by Senator Morrill from the Senate Committee on Public Buildings and Grounds and passed the Senate on April 5, 1890. This bill was favorably reported from the House Committee on Public Buildings and Grounds January 9, 1891, but at the close of the session it had not come before the House for action.

An appropriation of $25,000 for fire-proofing the so-called chapel of the west wing of the Smithsonian Building and for repairing the roof of the main building and the ceiling and plastering of the main hall of the building, having become available, plans for the contemplated improvements were prepared by the Architect of the Capitol, as directed by Congress, and work was begun in April, 1891. The old roof of the chapel was entirely removed and replaced temporarily by a wooden covering for the protection of the specimens contained in this part of the building. By the end of June gratifying progress had been made towards the construction of a safe, substantial iron and slate roof.

This appropriation of $25,000 was but a portion of the sum asked for to be used not only for fire-proofing the chapel and repairing the roof of the main building, but also for making other repairs upon the building, more especially in making more suitable provision for storing and handling the Government documents, the distribution of which Congress has intrusted to the Institution. Under the wording of the appropriation act it was found, however, that the expenditure of the appropriation was confined to the two items mentioned above. I have referred

elsewhere in this report to the special needs of the exchange department, on account of the over-crowded condition of the store-rooms occupied by the Government.

The new buildings erected or in process of erection for the collection of living animals, being all in the Zoölogical Park, are mentioned in the report upon the park.

RESEARCH.

I am gratified to report that it has been possible by reducing expenses in other directions to revert in some measure to an early practice of the institution, eminently consonant with its founder's purpose, that of offering aid in original research to certain investigations of much importance which were hindered by lack of means.

Among the special grants may be named that of $500 to Prof. A. A. Michelson, of Clark University, for continuing his important work upon a universal standard of measure founded on the wave-length of light; also a sum of $600 placed at the disposal of Prof. E. W. Morley, to procure a special apparatus for determinations of the density of oxygen and hydrogen, an investigation requiring extreme precision and delicacy of manipulation, and promising results of wide application; while $200 was placed at the disposal of Dr. Wolcott Gibbs, for investigations at his laboratory in Newport upon chemical compounds.

To Prof. E. S. Holden, director of the Lick Observatory, California, a grant of $200 was made, to assist in perfecting his apparatus for securing photographs of the moon. The results of his studies in this field Prof. Holden has offered to place at the disposal of the Smithsonian Institution for publication at some future day, should it seem desirable.

Prof. Pickering, director of the Harvard Observatory, has also placed at the disposal of the Institution for publication a very valuable series of photographs of the moon, which have been secured at the Harvard Observatory, and which will be supplemented by photographs to be taken at the Harvard Observatory high-altitude station in the mountains of Peru.

The director of the Paris Observatory, Admiral Mouchez, has likewise promised his co-operation in securing lunar photographs of the highest degree of excellence now attainable.

With the aid of these three prominent observatories, which have given especial attention to the subject of lunar photography, it is proposed to prepare a volume representing upon a large scale the best results that can be secured, thus placing on record a detailed description of the lunar surface, the value of which for comparison with observations and photographs of the future can scarcely be over-estimated.

In furtherance of the plan for the establishment of standard sizes of screws and of diameters of tubing, etc., for astronomical and physical apparatus—a subject which has received the attention of committees of the National Academy of Science, as also of the American Association

for the Advancement of Science—a few standards have been tentatively adopted, and copies of these are attainable by all interested in securing uniformity in this class of work.

I have referred above to researches in physical science alone; the work of individual members of the Institution and of others in the natural sciences is given in connection with the portion of the report relating to the Museum. I may, however, state that certain physical investigations, which have been made under the personal direction of the Secretary of the Institution at private charge and not at the cost of its funds, are about being published in a volume of its Contributions,* in accordance with a policy long since counseled by the Board of Regents.

*Astro-physical Observatory.*—I may recall briefly here the circumstances which have led to the establishment of an astro-physical observatory as a part of the Smithsonian Institution.

In the first report that I had the honor to present to the attention of the Regents in 1888 I stated that preparations had been made by the late Secretary, Prof. Baird, to establish an astro-physical observatory and laboratory, in order that renewed attention might be given to the study of physical science. It was there reported that, in view of the fact that the construction of delicate instruments would occupy a considerable time, orders had already been given for the most essential pieces of apparatus for conducting investigations in radiant energy.

A special interest was taken in the proposed astro-physical observatory by the late Dr. J. H. Kidder, formerly Curator of Exchanges in the Smithsonian Institution, and the sum of $5,000 was received from his executors for this purpose under circumstances detailed in my last report. A like sum of $5,000 was presented personally to the Secretary by Dr. Alexander Graham Bell for prosecuting physical investigations, and particularly those upon radiant energy, and this sum was, with the consent and approval of the donor, placed to the credit of the Smithsonian Institution upon the same footing as the Kidder bequest.

A temporary wooden building of the simplest possible construction has been erected in the Smithsonian grounds just south of the main building, having been begun on the 18th of November, 1889, and finished about the 1st of March, 1890. This building is not to be regarded as an entirely suitable or permanent housing for the instruments. Its location, close to travelled streets, is unsuited for refined physical investigation, but the preliminary adjustment of the instruments and certain classes of work can be effectively and conveniently carried on here.

The principal instrument is a specially constructed siderostat by Sir Howard Grubb, of Dublin, Ireland. This instrument is in position. A spectro-bolometer, the outcome of many years' experience, has been made under my personal direction by William Grunow & Son, of New York, and has been received and mounted. A galvanometer, designed

*Experiments in Aero-dynamics, Smithsonian "Contributions to Knowledge," No 801, Vol. XXVII.

for the particular class of work in view, has been received, and was the last of the principal pieces of apparatus (provided for from the Smithsonian fund) to be put in place. The outfit is now in the main complete.

This country has no observatory devoted exclusively to astro-physical research, though England, France, and Germany have maintained for a number of years at a considerable expense observatories for the study of the physical condition of celestial bodies. I therefore indulged the hope that, in presenting the matter to Congress as previously reported, a request for a small annual appropriation for the maintenance of the observatory thus founded and equipped might meet with favorable consideration. I may say that the amount asked for ($10,000 for annual maintenance) has been appropriated, and will be available during the coming fiscal year.

In adjusting and determining the constants of the instruments, a work involving considerable labor, I have had the valuable assistance of Prof. C. C. Hutchins, of Bowdoin College, during a portion of the summer vacation. No permanent appointments of the assistants who will be required to carry on the investigations contemplated will be made until after the appropriation shall have become available.

## EXPLORATIONS.

The explorations of chief importance carried on by the Institution have been conducted by the Bureau of Ethnology and by the National Museum, and to the reports of these departments reference should be made for details.

## PUBLICATIONS.

The publications for the year have continued to represent the usual standard both in the number and in the general character of the several issues.

*Smithsonian Contributions to Knowledge.*—Mention may be made here of a publication embracing a collection of twenty-three colored plates illustrating the forest trees of North America, an unfinished work undertaken by the late Dr. Asa Gray, many years ago, which although in the quarto form of the Contributions to Knowledge, will not be included in volumes of that series. While no memoir has been actually published during the year, a paper presenting an account of some new experiments in aero-dynamics (already referred to) is in course of preparation, and will probably be through the press in August. It will not much exceed 100 quarto pages of letterpress, and will be illustrated by about ten plates.

*Smithsonian Miscellaneous Collections.*—A memoir on "The Corrections of Sextants for errors of Eccentricity and Gravitation," by Mr. Joseph A. Rogers, of this city, presents a good discussion of the subject, and has a practical as well as a theoretical value. A "Bibliography of the

Chemical Influence of Light," by Mr. Alfred Tuckerman, belongs to the growing class of reference aids to investigators and students, rendered necessary by the rapidly increasing volume of scientific literature.

In the Miscellaneous Collections for the year a number of articles from the general appendix to the annual reports, commonly prepared at the expense of the Institution, have been considered worthy of re-publication as separate essays, and will probably find their place ultimately in volumes of this series.

*Smithsonian annual reports.*—The annual report of the Regents to Congress on the operations and condition of the Institution for the year ending June 30, 1888, was received more promptly than usual, and has been largely distributed. The annual report of the Regents on the operations and condition of the U. S. National Museum for the same period has also been received and widely distributed. The annual report of the Regents to Congress on the Institution, for the year ending June 30, 1889, has in addition been received and distributed, and the annual report of the Secretary to the Board of Regents for the year ending June 30, 1890, has been issued during the year.

A full descriptive list of the Smithsonian publications for the year will be given in the appendix.

## SMITHSONIAN INTERNATIONAL EXCHANGE SERVICE.

The work of the Smithsonian Institution through which it is perhaps most widely known is its exchange service, whereby in a direct and tangible manner it effects one of the objects of its founder, "the diffusion of knowledge among men."

The exchange service was established very early in the history of the Institution, when communication between scientific men, particularly between those of the Old and of the New World, was slow and expensive. Its object was to distribute the Smithsonian publications, and to furnish at the same time a channel through which the publications of scientific men, societies, and institutions in this country might be sent to correspondents abroad, and similar publications from abroad might be received and distributed in America. The Institution received hearty coöperation in every direction. The chief learned societies in different parts of the world offered their aid as distributing centers of exchange documents, and many of the larger steamship companies generously consented to carry exchange boxes free of freight charges; foreign governments gave their aid, and in 1854 Prof. Henry announced in his report that there was "no port to which the Smithsonian parcels are shipped where duties are charged on them, a certified invoice of contents by the Secretary being sufficient to pass them through the custom-house free of duty. On the other hand, all packages addressed to the Institution arriving at the ports of the United States are admitted without detention, duty free. This system of exchanges is therefore

the most extensive and efficient which has ever been established in any country."

The service was immediately taken advantage of by the Bureaus of the United States Government, and between the years 1851 and 1867 it is estimated that over 20,000 packages of Government publications were carried by the exchange service, at an estimated cost to the private funds of the Institution of over $8,000.

In 1867 Congress recognized the efficiency and importance of this branch of the Smithsonian work by assigning to it the duty of exchanging fifty copies of all documents printed by order of either House of Congress, or by the United States Government Bureaus, for similar works published in foreign countries, and especially by foreign governments. This at once absorbed a very considerable part of the funds which it was deemed expedient to devote to exchange purposes; for nearly thirteen years the burden of the expense being almost entirely borne by the Smithsonian fund.

It is not necessary to repeat here the details of the exchange relations with the Government, as they have been given at length in previous reports, but I beg to call attention briefly to the summary presented last year in these words:

The following sums have been expended from the Smithsonian fund for the support of the international exchange system, in the interests and by the authority of the National Government, namely, $38,141.01 in excess of appropriations advanced from January 1, 1868, to June 30, 1886, for the exchange of official Government documents, and $7,034.81 in excess of appropriations from July 1, 1886, to June 30, 1889, advanced for the purpose of carrying out a convention entered into by the United States, or an aggregate of $45,175.82.

No account is here made of the rent value of the rooms occupied by the exchange bureau, though the rooms are urgently needed for the special purposes of the Institution.

In accordance with a resolution of the Board of Regents, a memorandum setting forth the above facts was transmitted on the 20th of May, 1890, to the Hon. Benjamin Butterworth, a member of the Board, in the House of Representatives, for the purpose of taking the necessary steps to procure a return by Congress to the Smithsonian fund of the sum last mentioned, namely, $45,175.82.

The value of the exchange service having become widely known and appreciated, efforts were made by various countries to establish more formal international relations for the purpose of securing an increase in its benefits, and on the 15th of March, 1886, plenipotentiaries from the United States and various other nationalities signed a convention at Brussels by which their respective governments definitely assumed the exchange of official documents and of scientific and literary publications between the countries interested.

Referring now more especially to the work of the exchange bureau during the past year and to its steady and rapid growth, it will be seen in the Appendix that no less than 100 tons of books passed through the

office, representing 90,666 packages—an increase of 8,094 packages over the number handled during the preceding year. Upon the exchange books accounts of publications received and transmitted are kept with 18,848 societies, institutions or individuals.

The expenditures on account of the exchange service have amounted to $20,382.21, of which $17,000 were appropriated directly by Congress, $3,361.12 were repaid by Government bureaus, and $9.95 were paid by State institutions and others, leaving a small deficiency to be met by the Smithsonian Institution.

While the expenses of the exchange service, it will be observed, are in the absence of rent charge now nearly met by the sum appropriated by the General Government, this end is only effected at the cost of dispatch; and even this slow freight is in many cases due to the liberality of the ocean steamship companies, a fact to which allusion has been made in all recent reports. While there seemed to be no impropriety in accepting the generosity of these companies when it was to be regarded as a direct contribution to the philanthropic aims of the Institution, it does not seem proper, where so much of the freight now carried is Government property and the service is conducted under an international treaty, that we should impose on this liberality further, yet if this privilege should be withdrawn the service would be most seriously crippled.

An appropriation is also needed to give effect to the treaty of Brussels, which calls for an immediate exchange of parliamentary annals. A bill making an appropriation of $2,000, estimated as necessary for this purpose, passed the Senate, but failed to come up for consideration in the House of Representatives.

I may mention also that the difficulty of making provision for the storage of the surplus copies of Government publications intended for foreign exchange is each year becoming greater, and it is necessary to store many boxes of valuable documents in a basement which past experience has shown is liable to be flooded with water. This fact I consider it my duty to bring to the attention of Congress that such action as it deems fit may be taken to protect this public property.

## LIBRARY.

The accessions to the library have been recorded and cared for as during the last fiscal year. The following statement shows the number of books, maps, and charts received from July 1, 1890, to June 30, 1891:

| | Octavo or smaller. | Quarto or larger. | Total. |
|---|---|---|---|
| Volumes | 1,844 | 837 | 2,681 |
| Parts of volumes | 9,439 | 11,086 | 20,525 |
| Pamphlets | 3,130 | 639 | 3,769 |
| Maps | | | 319 |
| Total | | | 27,294 |

Of these accessions, 7,720 (namely 424 volumes, 6,413 parts of volumes, and 883 pamphlets) were retained for use at the National Museum Library, and 754 medical dissertations were deposited in the Library of the Surgeon-General, U. S. Army; the remainder were promptly sent to the Library of Congress on the Monday following their receipt.

The reading room continues to be well used by those who have occasion to consult the current scientific literature. As the number of boxes available for holding periodicals is strictly limited by the size of the room the only way to make room for the installation of new and desirable journals is to remove those which are found to be least consulted or which have ceased publication during the year. This was done by the librarian during the spring of 1891.

Four hundred and fifty-six boxes are now occupied, leaving sixteen to be filled by new accessions during the next fiscal year. Of the journals removed from the reading room, such as would be of permanent use in the scientific work of the Institution were transferred to the Library of the National Museum; the remainder were forwarded to the Library of Congress.

It will be remembered that when I first became connected with the Institution as assistant secretary I formulated a plan, the details of which will be found in my report for 1887-'88, for enlarging the accessions to the library so as to cover more completely the field of scientific knowledge, and also for completing the series of scientific journals already in the possession of the Institution which for any reason are imperfect.

As stated in my report for 1889, the work of executing the plan was commenced on June 1 of that year and has been assiduously carried on ever since. It is now rapidly approaching completion, and it is estimated that it will require but a few months of the next fiscal year to bring the work as originally planned to a termination. So rapid, however, has been the advance of scientific thought in the interval since the preparation of the list that, although the utmost vigilance has been exercised in watching for the appearance of new scientific journals, it is probable that very many such have newly appeared which have escaped notice. A certain amount of supplementary work will, therefore, be required to make the exchange lists conform with the present status of the periodical literature of science and in a very minor degree of art.

A list of the new exchanges will be found in the Appendix (Report of the Librarian), which also includes a list of important accessions outside of the regular serials.

It may be remembered that in my report for 1887-'88, I spoke of a certain limited number of books, not forming part of the Smithsonian deposit in the Library of Congress, obtained by purchase from the Smithsonian fund and retained at the Institution under the name of the "Secretary's Library."

These books are mostly, but not exclusively, books of scientific refer-

ence, certain art serials being included among them, and though all are kept in the Secretary's office they are at the service, under certain necessary restrictions, of all connected with the Institution.

This collection numbers at present nearly 300 volumes, and while it would be highly desirable to enlarge it still further, this is rendered almost impracticable, because the Secretary's office is already filled nearly to its utmost capacity. It is not possible either to place the collection of works of reference under the immediate charge of the librarian, as the rooms which he occupies are already over-crowded, while the room on the same floor, which would naturally be the one to which the library would be extended, is occupied as a shipping office by the Bureau of International Exchanges.

It is to be hoped in the interest of the library, then, as well as of the Bureau itself, that Congress will provide the additional quarters which have been asked for the latter.

## MISCELLANEOUS.

*Portraits of Regents.*—The Institution is under obligation to the Chief of the Bureau of Engraving and Printing for copies of engraved portraits of several former Regents of the Institution, which had been prepared for official purposes.

*Statue of Robert Dale Owen.*—A bill appropriating $20,000 for a statue of Hon. Robert Dale Owen, of Indiana, who was among the first and most actively interested Regents of the Institution, was introduced in the Senate on December 9, 1890, by the Hon. Daniel W. Voorhees, and was passed on the same day by the Senate, but failed to secure favorable action in the House of Representatives.

*Statue of Prof. Baird.*—I have the honor again to call the attention of the Regents to the bill which was passed by the Senate in February, 1888, providing for a bronze statue of Prof. Baird in recognition of the distinguished services rendered his country, and I venture to express the hope that this subject may receive the earnest consideration of his many warm friends in both Houses of Congress.

*Capron collection of Japanese works of art.*—An appropriation of $10,000 for the purchase of the Capron collection, which has been for several years on deposit in the Museum, was included in the sundry civil act for the year 1891–'92, thereby securing this valuable collection of Japanese works of art to the Government.

*Perkins collection of prehistoric implements.*—The deficiency bill approved October 1, 1890, contained an appropriation of $7,000 to enable the Secretary of the Smithsonian Institution to purchase of Mr. Frederick S. Perkins his collection of prehistoric implements. This sum was duly paid to Mr. Perkins and the collection received and deposited in the National Museum.

*Meteorological records.*—In accordance with arrangements made with the Chief Signal Officer, U. S. Army, Gen. A. W. Greely, the meteoro-

logical records, forming a portion of the archives of the Smithsonian Institution, and representing a considerable amount of work accomplished by it in earlier days, have been temporarily transferred to the Signal Office, and deposited there in a fireproof vault for custody and storage. These records serve to carry back the meteorological observations of the Signal Service as far as the year 1840. They consist of:

346 bound volumes of monthly reports by observers from 1840 to 1873, inclusive.
6 volumes of records made at the Smithsonian Institution.
47 pasteboard boxes of miscellaneous records by locality.
64 paper packages of miscellaneous records, scraps, etc.
15 miscellaneous note-books.
1 large package of manuscript folio sheets, observations, survey northwestern lakes.
7 royal octavo bound volumes, printed reports.

*Bequest of Dr. J. R. Bailey.*—Information has been received that Dr. J. R. Bailey, late of Olmstead, Ky., has devised his library to the Smithsonian Institution, and the necessary steps will be taken to acquire possession.

*Assignment of rooms for scientific work.*—A basement room especially suited for delicate physical measurements on account of its freedom from tremor has been used by the officers of the United States Coast and Geodetic Survey for making pendulum observations.

*Stereotype plates.*—Owing to the more urgent demands of current work, but little progress has been made in examining and re-arranging the stereotype plates of the publications of the Institution. I hope to make arrangements during the coming year to push this work to an early completion.

The stereotype plates and engravers' blocks are cheerfully placed at the disposal of publishers for supplementing or illustrating scientific works privately issued.

## U. S. NATIONAL MUSEUM.

In my representations to Congress during recent years I have felt called upon to insist upon two points: First, that the collections have increased so rapidly that additional space is required for their proper administration, and that unless more space be provided, the growth of the national collections must, to a large extent, be interfered with; and secondly, that the collections, although growing rapidly in certain directions, are not developing in such a symmetrical and consistent manner as is essential to the necessities of the work.

I feel justified in assuming that it is the intention of Congress that the National Museum of the United States shall be, as far as a museum can be, a worthy exponent of the natural resources and scientific achievements of the nation, that it shall be worthy of the attention of visitors to the capital, and that it shall perform its proper functions as one of the scientific departments of the Government, and shall also

promote the scientific and educational interests of the country at large. This being granted, it is essential not only that the collections should grow, and grow rapidly, in order to keep pace with the material and intellectual development of the country, but also that a competent staff of curators should be constantly at work, developing by scientific study and publishing under the auspices of the Government the facts which are essential to the correct understanding of the material under their charge, preserving the collections from destruction, and arranging and classifying them in such a manner that they shall be immediately accessible to the students of science from all parts of this country and from abroad, who are constantly visiting Washington for the purpose of consulting the collections of the Government in connection with their own scientific studies.

On this account it is a critical time in the history of the Museum. Such is the competition for material that the National Museum of the United States is unable to hold its own not only with foreign governments and with local museums in other American cities, but is even at a disadvantage when its collections are compared with those of many private collectors. For instance, there are in this country several private collections of minerals, archæological objects, as well as of specimens relating to the various departments of zoölogy, the promoters of which can seemingly afford to pay more for any choice objects needed to complete their collections than can the Government of the United States. It is somewhat mortifying to see collections of American objects, which a few years hence will undoubtedly be recognized by everyone as essential to be preserved in the National Museum of this country, taken away to foreign countries because their value is more highly appreciated there than at home. Whatever may be considered the proper functions of the National Museum of the United States in regard to other matters, it will always be expected that in the national capital the collections illustrating ethnology and the natural resources of this continent will be fully as imposing as in other similar establishments, and that the national collections should compare favorably with those in other American cities, and will in respect to American material surpass those in any foreign capital.

It is not my wish to depreciate the importance of what has already been done by the Government for the advancement of scientific research, for in most of the fields in which really serious work has been accomplished, the National Museum is at least equal, and often superior to, any other in the United States, but the effort to maintain the collections on this footing will be much more difficult hereafter than in the past. It would be unfortunate if students of American natural history and ethnology, who have hitherto been obliged to come to Washington in connection with their studies, should hereafter find it more advantageous to consult private collections in other parts of this country.

*Growth of the collections.*—The growth of the national collections

since 1881, when the new building was completed, has been probably unprecedented in the history of museums; and this has rendered it necessary to employ a force of men proportionately larger than is found in most museums, in order to utilize the material to the best advantage. Notwithstanding this fact, the aggregate appropriation made by the United States for museum purposes is smaller than that of many foreign governments.

The Museum building has now been occupied one decade, and during this time the total number of specimens of all kinds catalogued and ready for exhibition or study has increased from about 193,000 to more than 3,000,000.

*Curatorships.*—The scientific departments of the Museum are not yet all supplied with curators. The number of separate departments and sections is now 33, and less than one-third of this number is under the charge of curators paid from the Museum fund and able therefore to devote all their time to Museum work. By far the larger number of the scientific departments is under the charge of officers of other departments of the Government service (for instance, the Geological Survey, the Department of Agriculture, the Bureau of Ethnology, and the Fish Commission), who, although they render most important services in the way of supervision and general direction of the work, are necessarily so occupied with their own peculiar administrative duties, that they can not devote very much of their time to the development of the collections under their charge. Three important zoölogical departments have for a great many years been under the charge of officers of the Fish Commission. Under the administration of Professor Baird, who was at once Commissioner and head of the Museum, it was considered proper that they should give a considerable portion of their time to Museum work, which was directly tributary to the results which Professor Baird was desirous of producing in connection with the service under his charge. Soon after the death of Professor Baird it became necessary for these men, although still retaining their positions as honorary curators in the Museum, to devote nearly all of their time and attention to matters relating to the Fish Commission. If it were possible to employ experienced men as assistants in these departments, as well as under the other honorary curators, important advantages would manifestly result. At all events, it is absolutely necessary to have a curator or assistant curator appointed to take charge of the work in each department, in order that the material collected at considerable expense by the Government shall be properly arranged and identified, and that the results of the work shalll be published for the advancement of science. This, however, can not be done until Congress shall see fit to make more liberal appropriations for the maintenance of the Museum.

*Increase in correspondence.*—Within the past three years there has been an astonishingly large increase in the number of calls upon the

Museum, very largely by Members of Congress and through them by their constituents, for scientific information of all kinds, for collections in various departments of natural history (scientifically arranged and named, for the use of schools and colleges), for books and services of many kinds, including the examination and identification of minerals, ores, animals, plants, etc. It is quite safe to say that during the last three or four years the correspondence of the Museum has quadrupled. Special pains have been taken not only to reply to all communications in full and with great care, but to reply promptly, in accordance with the constantly increasing demands for rapid action on the part of the public officers in Washington.

*Salaries.*—The salaries paid to employés, especially clerks, copyists, and skilled mechanics, are much less than those which are paid for similar services in the Executive Departments. Many of our most useful assistants have been drawn away from the staff and called to places in the Executive Departments, where, although the responsibilities are no greater, they receive much larger rates of pay. It is quite essential for the efficiency of the service that the stipend of persons of this class should be increased—not necessarily to the amounts current in the Executive Departments, but to such figures as will render it possible to retain useful employés after they have been laboriously trained and prepared for their work. Within a year or two, three stenographers and typewriters have been drawn away from the office of the Assistant Secretary in charge of the Museum.

*Need of additional assistance.*—It is absolutely necessary to have the collections taken care of as fast as they are received, and although they can not all be prepared for exhibition, owing to lack of assistance as well as want of exhibition space, yet the mere preservation of the specimens from destruction implies very great labor, especially in the case of zoölogical objects. Taking into consideration the fact that there are now about thirty-three distinct scientific departments in the Museum, to each of which, on an average, three persons at least are attached, it will be readily understood that, after all the expenses have been met for the preservation, care, and exhibition of the specimens, very little remains for maintaining the administrative force. The need of additional intelligent clerical assistance is felt in every branch of the administrative work. For instance, to the regular duties of the chief clerk's office has been necessarily added the management of the financial matters connected with the preparation of the exhibit for the World's Columbian Exposition. In the division of correspondence the increase of work has been very great, and no less than 10,000 letters are now required to be written where 2,500 sufficed only a very few years ago. A similar increase of work might be cited in all the other administrative offices, but the means for providing adequate assistance are not at hand. In this way it has happened that the appropriations have been largely used in the maintenance of the scientific departments to the great disadvantage and

impairment of the administrative work of the Museum. These matters have already been represented in strong terms in previous reports, and the Secretary has taken every available means of calling attention to the dangers which beset the National Museum owing to the insufficiency of the appropriations made by Congress for its maintenance. It is only necessary to add in this place that the sum mentioned in the statement accompanying the report for 1889 (pp. 35–38), as then required for services, was prepared in response to a Senate resolution asking for a "schedule of the classified service of the officers and employés of the National Museum," and represented the needs of the Museum *at that time*. Since then there have been large increases in almost every department of the Museum work, and if I were now preparing a similar statement, I should find it necessary to make a corresponding increase in the totals of the several divisions of the schedule referred to.

The operations of the Museum in all of its departments for the fiscal year ending June 30, 1891, are fully discussed in the report of the Assistant Secretary in charge of the Museum, and therefore reference to the work of the Museum will here be restricted to some of the most important general features.

*Accessions.*—Ten years ago the National Museum moved into a new building, and the present year thus marks the close of a very important decade in its history. The increase in the collections during this period has been unexpectedly large, the accessions from all sources now numbering 3,028,714 specimens. In 1882, when the first census of the collections was made, the total number of specimens was estimated at less than 195,000. The totally inadequate space provided for this vast accumulation of material has been so frequently commented upon in previous reports, that it is not necessary to reiterate the urgent recommendations which have been made to Congress for another building.

| Name of department. | 1882. | 1883. | 1884. | [1]1885–'86. | 1886–'87. | 1887–'88. | 1888–'89. | [2]1889–'90. | 1890–'91. |
|---|---|---|---|---|---|---|---|---|---|
| Arts and industries: | | | | | | | | | |
| Materia medica | ....... | 4,000 | 4,442 | 4,850 | 5,516 | 5,762 | 5,942 | [3]5,915 | 6,083 |
| Foods | ....... | 1,244 | 1,580 | 822 | 877 | 877 | 911 | 1,111 | 1,111 |
| Textiles | ....... | ....... | 2,000 | 3,063 | 3,144 | 3,144 | 3,222 | 3,288 | 3,288 |
| Fisheries | ....... | ....... | 5,000 | 9,870 | 10,078 | 10,078 | 10,078 | 10,080 | 10,080 |
| Animal products | ....... | ....... | 1,000 | 2,792 | 2,822 | 2,822 | 2,948 | 2,949 | 2,994 |
| Graphic arts | ....... | ....... | ....... | ....... | ....... | ....... | ....... | [4]600 | 974 |
| Transportation and engineering | ....... | ....... | ....... | ....... | ....... | ....... | ....... | [4]1,250 | 1,472 |
| Naval architecture | ....... | ....... | 600 | ....... | ....... | ....... | 600 | [5]600 | [5]600 |
| Historical relics | ....... | ....... | ....... | 1,002 | 13,634 | 14,640 | 14,990 | 20,890 | 23,890 |
| Coins, medals, paper money, etc | ....... | ....... | ....... | 1,005 | | | | | |
| Musical instruments | ....... | ....... | ....... | 400 | 417 | 427 | 427 | 447 | 542 |

[1] No census of collection taken.

[2] The actual increase in the collections during the year 1889–'90 is much greater than appears from a comparison of the totals for 1889 and for 1890. This is explained by the apparent absence of any increase in the Departments of Lithology and Metallurgy, the total for 1890 in both of these departments combined showing a *decrease* of 46,314 specimens, owing to the rejection of worthless material.

[3] Although about 200 specimens have been received during the year, the total number of specimens in the collection is now less than that estimated for 1889, owing to the rejection of worthless material.

[4] The collection now contains between 3,000 and 4,000 specimens.

[5] No estimate of increase made in 1890 or 1891.

| Name of department. | 1882. | 1883. | 1884. | [1]1885-'86. | 1886-'87. | 1887-'88. | 1888-'89. | [2]1889-'90. | 1890-'91. |
|---|---|---|---|---|---|---|---|---|---|
| Arts and industries—Continued. | | | | | | | | | |
| Modern pottery, porcelain, and bronzes | ...... | ...... | ........ | 2,278 | 2,238 | 3,011 | 3,011 | 3,132 | 3,144 |
| Paints and dyes | ...... | ...... | ........ | 77 | 100 | 100 | 100 | 197 | 197 |
| "The Catlin Gallery" | ...... | ...... | ........ | 500 | 500 | 500 | 500 | ([3]) | ([3]) |
| Physical apparatus | ...... | ...... | ........ | 250 | 251 | 251 | 251 | 263 | 273 |
| Oils and gums | ...... | ...... | ........ | 197 | 198 | 198 | 213 | 1,112 | 1,112 |
| Chemical products | ...... | ...... | ........ | 659 | 661 | 661 | 688 | | |
| Domestic animals | ...... | ...... | ........ | ........ | ........ | ........ | ........ | 66 | 97 |
| Ethnology | ...... | ...... | 200,000 | 500,000 | 503,764 | 505,464 | 506,324 | 508,830 | 510,630 |
| American aboriginal pottery | ...... | ...... | 12,000 | 25,000 | 26,022 | 27,122 | 28,222 | 29,209 | 30,488 |
| Oriental antiquities | ...... | ...... | ........ | ........ | ........ | ........ | 850 | 3,485 | 3,487 |
| Prehistoric anthropology | 35,512 | 40,491 | 45,252 | 65,314 | 101,659 | 108,631 | 116,472 | 123,677 | 127,761 |
| Mammals (skins and alcoholics) | 4,660 | 4,920 | 5,694 | 7,451 | 7,811 | 8,058 | 8,275 | 8,836 | 9,301 |
| Birds | 44,354 | 47,246 | 50,350 | 55,945 | 54,987 | 56,484 | 57,974 | 60,219 | 62,601 |
| Birds' eggs and nests | ...... | ...... | 40,072 | 44,163 | 48,173 | 50,055 | 50,173 | 51,241 | 52,166 |
| Reptiles and batrachians | ...... | ...... | 23,495 | 25,344 | 27,542 | 27,664 | 28,405 | 29,050 | 29,935 |
| Fishes | 50,000 | 65,000 | 68,000 | 75,000 | 100,000 | 101,350 | 107,350 | 122,575 | 127,312 |
| Vertebrate fossils | ...... | ...... | ........ | ........ | ........ | ........ | ........ | [4]512 | 521 |
| Mollusks | 33,375 | ...... | 400,000 | 460,000 | 425,000 | 455,000 | 468,000 | 471,500 | 476,500 |
| Insects | 1,000 | ...... | 151,000 | 500,000 | 585,000 | 595,000 | 603,000 | 618,000 | 630,000 |
| Marine invertebrates | 11,781 | 14,825 | 200,000 | 350,000 | 450,000 | 515,000 | 515,300 | 520,000 | 526,750 |
| Comparative anatomy: | | | | | | | | | |
| Osteology | 3,535 | 3,640 | 4,214 | 10,210 | 11,022 | 11,558 | 11,753 | 12,326 | 12,981 |
| Anatomy | 70 | 103 | 3,000 | | | | | | |
| Palæozoic fossils | ...... | 20,000 | 73,000 | 80,482 | 84,491 | 84,649 | 91,126 | 92,355 | 92,970 |
| Mesozoic fossils | ...... | ...... | 100,000 | 69,742 | 70,775 | 70,925 | 71,236 | 71,305 | 79,754 |
| Cenozoic fossils | (Included with mollusks.) | | | | | | | | |
| Fossil plants | ...... | 4,624 | 7,291 | 7,429 | 8,462 | 10,000 | 10,178 | 10,507 | 10,685 |
| Recent plants[5] | ...... | ...... | ........ | 30,000 | 32,000 | 38,000 | 38,459 | 39,654 | 80,617 |
| Minerals | ...... | 14,550 | 16,610 | 18,401 | 18,601 | 21,896 | 27,690 | 37,101 | 44,236 |
| Lithology and physical geology | 9,075 | 12,500 | 18,000 | 20,647 | 21,500 | 22,500 | 27,000 | [6]32,762 | 64,162 |
| Metallurgy and economic geology | ...... | 30,000 | 40,000 | 48,000 | 49,000 | 51,412 | 52,076 | | |
| Living animals | ...... | ...... | ........ | ........ | ........ | 220 | [7]491 | ........ | ........ |
| Total | 193,362 | 263,143 | 1,472,600 | 2,420,944 | 2,666,335 | 2,803,459 | 2,864,244 | 2,895,104 | 3,028,714 |

[1] No census of collection taken.

[2] The actual increase in the collections during the year 1889-'90 is much greater than appears from a comparison of the totals for 1889 and for 1890. This is explained by the apparent absence of any increase in the Departments of Lithology and Metallurgy, the total for 1890 in both of these departments combined showing a *decrease* of 46,314 specimens, owing to the rejection of worthless material.

[3] Included in the historical collection.

[4] Only a small portion of the collection represented by this number was received during the year 1889-'90.

[5] Up to 1890 the numbers have reference only to specimens received through the Museum, and do not include specimens received for the National Herbarium through the Department of Agriculture. The figures given for 1890-'91 include for the first time the total number of specimens received both at the National Museum and at the Department of Agriculture for the National Herbarium.

[6] Collections combined in October, 1889, under Department of Geology. The apparent decrease of more than 50 per cent of the estimated total for 1889 is accounted for (1) by the rejection of several thousands of specimens from the collection, and (2) by the fact that no estimate of the specimens in the reserve and duplicate series is included. Of the total for 1890, about 16,000 specimens consist chiefly of petrographical material stored away for study and comparison in the drawers of table cases.

[7] Transferred to the National Zoological Park.

NOTE.—The fact that the figures for two successive years relating to the same collection are unchanged does not necessarily imply that there has been no increase in the collection, but that for some special reason it has not been possible to obtain the figures showing the increase.

*The World's Columbian Exposition.*—Mention was made in the last report of the provision made by Congress for holding an exposition in the city of Chicago in 1893 for the purpose of celebrating the four hundredth anniversary of the discovery of America by Christopher Columbus. Dr. G. Brown Goode was upon my nomination appointed by the President the representative of the Smithsonian Institution and the National Museum upon the Government Board of Managers and Control. During the latter part of the year the Treasury Department decided that between $30,000 and $40,000 were available for expenditure in connection with the preparation of the Government exhibits. This sum was apportioned by the Board among the executive departments, including the Smithsonian Institution, the National Museum and the Fish Commission: the Smithsonian Institution, including the National Museum and the Bureau of Ethnology, receiving about $6,000. This amount is of course entirely inadequate, except as affording the means of making a commencement, and would hardly suffice for the preparation of a satisfactory exhibit from any one department in the Museum. As soon as this money became available, however, several of the curators in the National Museum commenced to prepare plans for the exhibits of their departments, and a small force of taxidermists and mechanics was engaged. Mr. R. Edward Earll was appointed chief special agent in April, and will act as the executive officer under the direction of the representative of the Smithsonian Institution.

## BUREAU OF ETHNOLOGY.

Ethnological researches among the North American Indians has been continued by the Smithsonian Institution in compliance with acts of Congress, during the year 1890-'91, under the direction of Maj. J. W. Powell, who is also the Director of the U. S. Geological Survey.

The work of the Bureau of Ethnology has been conducted during the year in accordance with the system before reported upon and explained. A noteworthy feature of it is that the officers who as authors prepare the publications of the Bureau personally gather the material for them in the field, supplementing it by study of all the connected literature and by the consequent comparison of all ascertained facts. The continuance of the work for a number of years by the same zealous observers and students, who freely interchange their information and opinions, has resulted in their training with the acuteness of specialists, corrected and generalized by the factors of other correlative specialties.

At the close of the last fiscal year specific exploration of the mound area by the United States ceased, except so far as it was found necessary to correct errors and supply omissions. A large part of the results of the work of several past years is in print, though not yet issued. A plan of general archæologic field work has been practically initiated by a systematic exploration of the tidewater regions of the District of Colum-

bia, Maryland, Virginia, and the Ohio Valley, which determined among other points of interest that the implication of great antiquity to forms of stone implements of America which have hitherto been classed with European palæoliths in age as well as in fabrication has not been substantiated by the ascertained facts.

Careful exploration of the Verde Valley in Arizona followed that before made of other parts of the large southwestern region of the United States in which the presence of many extensive ruins has given rise to fanciful theories. The data as classified and discussed has shown that the hypothesis of a vanished race enjoying high civilization, which has been proposed to account for the architecture of the ruined structures, is unnecessary.

The attention already given to Indian languages has been continued, in recognition of the fact that some of them are fast passing beyond the possibility of record and study and that the ethnic classification of all of the Indian tribes can be made accurate only through the determination of their linguistic divisions and connections. The studies upon aboriginal mythology and religious practices has also been continued, with special attention to the ghost dances and "Messiah religion," which have produced important consequences bearing upon the problem of proper national dealing with the Indians. Official misconception of their religious philosophy, which has been forcedly transfigured by the absorption of Christianity so as to present more apparent than actual antagonism to civilization, has occasioned needless loss of life and treasure.

Further details respecting the work of the Bureau will be found in the report of its director, given in full in the Appendix.

## NATIONAL ZOOLOGICAL PARK.

The primary object for which Congress was asked to establish a National Zoological Park was to secure the preservation of those American animals that are already nearly extinct, and this object it was thought would be best secured by the establishment of a large inclosure in which such animals could be kept in a seclusion as nearly as possible like that of their native haunts. It was believed that, except for initial expenses for buildings and roads for the public, this could be done with an outlay comparatively small, probably not exceeding $50,000 a year; for, after the necessary land was once acquired and fenced in, smaller inclosures and paddocks could be set off and inexpensive barns erected at about this yearly charge.

It was, in the nature of things, inevitable that some provision should be made for the convenience of a curious and interested public, as well as for the care and well being of animals unaccustomed to the presence of man. For the first of these it was intended to set aside a considerable area, on which the principal buildings should be placed and

to which should be taken, as was expedient, such of the animals as might interest the public, the larger portion of the park being still considered as a natural preserve where animals need be disturbed by no unusual surroundings, and where it was hoped they might, after the time necessary for their acclimation, breed their young.

The maintenance of a park devoted to these purposes, that is, primarily to useful and scientific ends, and secondly to recreation, seemed to those interested in its success a legitimate tax upon national resources, but when Congress decided that one-half of the necessary expense should be raised by local taxation it seemed only fit that the tax-payers should be heard in their wish to have prominence given to the feature that principally interested them, and their chief interest was naturally in the Park as a place of recreation. That this was recognized by a considerable body in Congress became evident from the subsequent debates.

The moral right of the people of the District to ask consideration of their wishes for entertainment in return for the outlay which falls upon them can not be questioned, and so far as this could be recognized it introduced a tendency to provide an establishment more like an ordinary zoological garden, or permanent menagerie, than the comparatively inexpensive scheme at first contemplated.

In view of the circumstances an appropriation was asked of Congress, which was believed to be smaller than was consistent with the proper ultimate development of the park, but on an estimate which proposed to begin on the most economical scale. Thus, for the general maintenance of the collection, $35,000 was asked, which is about the same as the annual sum spent in the Central Park menagerie, New York, having an area of about 10 acres, and at least $10,000 less than is spent either at the zoological garden in Cincinnati or Philadelphia, each having an area of about 40 acres. When it is reflected that these latter enterprises are conducted for business purposes by business men, that they have their collections already nearly complete and purchase but few new animals, it will be seen that the sum asked for the maintenance of the 167 acres of the National Zoological Park with all the expensive animals yet to be procured was certainly not extravagant. Congress reduced this estimate to $17,500, a sum for which as a year's experience has now shown the Park can not be maintained.

For buildings, an appropriation of $36,850 was asked. In this connection it may be recalled that in the Philadelphia gardens the buildings and inclosures cost $194,705. The sum estimated was intended to cover all inclosures and structures of every character indispensable on the modest scale proposed. Congress reduced this to $18,000.

The average expense of preparing such uncultivated grounds in city parks elsewhere has proved to be at least $2,900 per acre. The sum of $29,500 was asked for that purpose, as no more than sufficient to fit

such portions of the park as were necessary for the immediate accommodation of the public. Congress reduced this to $15,000.

These reductions have not only obliged me to retard the development on the lines that had been laid down, but have increased the ultimate cost; for where living creatures are in question it is plain that they have not only to be fed and guarded but to be housed; and all this at once, under penalty of their loss. Congress has plainly intended that they should be preserved, and that some sort of roads and access for the public should be provided this year.

The result has necessarily been, that with every effort to obtain permanent results there has been a partial expenditure of the absolutely insufficient grant on enforced expedients of a temporary character, which are not in the interests of economy.

It is extremely desirable that a sum for emergencies be secured in the next appropriation. In carrying forward from the beginning novel and untried work of such varied character, unforeseen difficulties must inevitably arise, but no provision has been made for these, nor even for such readily anticipated emergencies as are caused, for instance, by floods in grounds traversed by a stream which has been known to rise 6 feet in less than half an hour.

The difficulties which these conditions have imposed on the administration of the park may be fairly called extreme, and the amount and character of what has been effected must be considered in this connection. In spite of these the result, I think, may be said to be, that at least as a source of interest and amusement to the people the park has exceeded the most sanguine expectations.

As the available funds were small it was necessary to limit the area of the park which should be first improved. It was found that the animals on hand could be accommodated within an area of 40 acres, and a tract of about that size was selected, extending along the main drive from Quarry road to Connecticut avenue through the most interesting portion of the park. This main road was laid out, graded, and metalled early in the fiscal year, and steps were taken to construct a permanent bridge over Rock Creek at the place where the road should pass. As was anticipated, the construction of the bridge presented serious engineering difficulties. Rock Creek is usually a quiet shallow stream, but becomes in times of freshet a powerful torrent. It was necessary to erect a structure that would withstand these floods and desirable that it should be one which would not mar the beauty of the valley. After a careful consideration of several designs, motives of economy compelled the erection of a bridge of wood and iron, resting upon stone piers 15 feet above ordinary water level, sufficient as an engineering structure but having no claim to beauty other than that of utility. At the close of the year these piers had been erected and the superstructure contracted for but not yet placed. In the meantime temporary in-

expensive wooden bridges have been in use. During the progress of the work they have been several times swept away or seriously injured.

A number of trees have been planted in different parts of the park, in some places for ornament, in others to secure the proper seclusion of animals. A considerable area of open land has been prepared for lawn and pasture grounds.

The development of the park has proceeded steadily during the year, the minimum of change in the natural features of the picturesque region being made on principle and independent of any considerations of economy. As the approach from the city by the way of the Quarry road could be made available at the least expense to the park, that road is adopted provisionally as the main carriage entrance. At the request of the Secretary the Commissioners of the District of Columbia expended a sum of $1,000 in grading and repairing this road, but while it has served a useful purpose it is still far from satisfactory as a principal avenue of approach. The grade is steep, the carriage way narrow, and the roadbed not sufficiently thick to endure heavy travel.

The system of roads contemplates other means of approach, especially a bridle path by the way of Ontario avenue, a footpath (which will probably be enlarged to a carriage road as means may permit) by the way of Woodley Bridge, extending along the creek through the park as far as the Klingle Bridge, and a carriage road entering from Connecticut avenue extended on the west side of the park, by which persons brought by the Rock Creek Railway can readily pass in. A winding footpath from the Adams Mill road leads by means of rudely constructed steps and a simple rustic bridge down the cliffs and across a narrow ravine into the occupied portion of the park.

Before animals could be safely kept in the park, it was necessary to inclose it so as to insure control of all the territory within its limits. A boundary fence was therefore built, and experience has shown it to be absolutely essential to the safety and well-being of the animals as well as to the preservation of the trees, shrubbery, and property of the park.

Near what is for the present the principal entrance is a disused quarry, from which arise precipitous cliffs and bold rocky ledges. It seemed particularly well fitted for the construction of dens and yards for bears. A series of caverns has been blasted in the rock and inclosed by a stout iron fence. Within the fence are large and commodious yards in which have been constructed bathing pools, with water flowing constantly from a large spring outside the park at the side of Quarry road. The result has been a place admirably adapted for the health and general welfare of the animals, as well as a most picturesque and striking feature. It has been found necessary, in order to protect the yards from falling dirt and débris swept down the cliffs by rains, to build a retaining wall on the ledge above the dens at once, and this has been done in part, for the reasons already stated, in such a manner as it is to

be feared will necessitate very early removal. It is most desirable that the boundary of the park, which now runs along the very edge of this precipice, should be carried back a few yards to thus avoid the expense of a costly permanent retaining wall.

A house for the bison has been built and another for animals requiring warmer winter quarters is in course of construction, a portion of it being already occupied. It will not be possible to complete this house upon the original plan under the present appropriation, but it was deemed a wise economy to accept a design which could be partially completed and extended as the need for more room became pressing and other means should become available.

Already the establishment in the United States of a National Zoological Park under the management and guidance of the Smithsonian Institution has attracted the attention of similar institutions and of naturalists in other countries, and liberal offers of gifts and exchanges have been made.

From Sumatra, from the islands of the Pacific, from the shores of Alaska, and from our own national parks, have come offers of gifts or terms of purchase, but I regret to say that it has been necessary to defer acceptance of all these offers owing to lack of funds even to pay transportation.

## NECROLOGY.

### GEORGE BANCROFT.

It seems unnecessary to give here more than a brief outline of the connection of the distinguished historian, the Hon. George Bancroft, with the Smithsonian Institution.

Mr. Bancroft was elected by Congress a regent from the city of Washington, December 11, 1874. He was appointed chairman of a special committee to memorialize Congress for a building for the National Museum; he served on a committee under whose direction a portrait of Prof. Henry was painted, and on January 20, 1875, was elected a member of the executive committee. He resigned from the Board in March, 1878, after serving four years. Mr. Bancroft died on January 17, 1891.

### WILLIAM TECUMSEH SHERMAN.

As in the case of Mr. Bancroft, any extended notice of the life of Gen. Sherman would seem entirely superfluous, but it is fitting that I should mention here his interested and valuable services upon the Board of Regents.

Gen. Sherman was elected by Congress a regent from the city of Washington, January 30, 1871, and became a member of the executive committee of the Board, March 9 of the same year. His resignation from the Board was presented November 12, 1874, on account of a change of residence from Washington to St. Louis.

The following extract from his letter of resignation expresses his deep interest in the Institution and his views as to its policy:

In thus severing my official connection with the Smithsonian, I beg leave to express to you and your associates my sense of the noble task in which you are engaged, and of my earnest prayer that the institution under your management will continue to fulfill its magnificent design.

A knowledge of science, that is, of the laws of nature, is so intimately connected with the advance of higher civilization that Mr. Smithson displayed unusual wisdom in so endowing his institution that it should give its principal labor to the increase of knowledge, to accumulating and securing new knowledge to be added to the old, which should be a special province of the universities of the whole earth. I therefore coincide with you perfectly in your special construction of the will, and hope that the Regents will continue to construe it literally as a legacy sacred in its nature and beneficial in the highest degree.

I beg you will assure your associates that among the many causes of regret at leaving Washington none impresses me more than that which forces me to sever my relations with the Regents of the Smithsonian Institution.

Upon his return to the capital he was re-elected by Congress a regent from the city of Washington, March 25, 1878, and again became a member of the executive committee on May 17 following. He served as chairman of a special committee of the Board to make arrangements for the funeral ceremonies of Prof. Henry, May 13, 1878, and was elected, January 15, 1879, by the Board to make an address at the memorial services of Prof. Henry in the United States Capitol. A few extracts from his address at the services on January 16, 1879, are eminently characteristic, and may be most appropriately quoted here:

From the beginning the living have paid homage to the virtues of the dead; for immortality is the dream of man. From Agra to Washington scarce a city, town, or village but contains some monument designed to perpetuate the memory of one who has passed from earth. Mountains have been excavated, pyramids built, temples have been erected, and granite, marble, and bronze shaped into every conceivable form to give expression to honor, respect, affection, and love for some dead hero, warrior, statesman, or philosopher. These earthly tributes can be of no service to the dead, but they form lasting records of deeds held honorable among men; are strong incentives to noble acts in the present, and mark a steady progress toward that better condition which is the ultimate destiny of the human race.

We are not assembled to-night to shape in marble, or granite, or bronze the human form of our countryman and friend, Prof. Joseph Henry, but in order that those who knew him best may, by simple tributes of thought and feeling, bear public testimony to the merits of one who in our day stood forth a most resplendent type of moral and intellectual manhood, and who, with little thought of self, rendered eminent service in the cause of mankind. He needs no monument, for where-ever man goes or human thought travels the poles and continuous wires will remind him that to Prof. Henry of all men we are most indebted for the inestimable blessings of the telegraph.

* * * * * * *

It was a scientific Englishman, a skillful analytical chemist of London, who conceived the thought and provided the means whereby Prof. Henry was enabled to accomplish so much further good. Arts may have been lost or forgotton, because no longer needed, and the world's libraries and universities already possessed in abundance the vast accumulations of knowledge which had for ages been garnered and stored away in these valuable repositories of learning, yet nature remained so bountiful that there could be no danger that her fountains would become exhausted, and Mr. Smithson provided for an institution which accepts all the past, and provides only for the future. He endowed munificently the institution (which bears his name here in Washington) for collecting new knowledge, and for distributing it to all parts of the earth. Great was the conception, generous the endowment, and fortunate that the execution fell to the lot of Prof. Henry.

* * * * * * *

For this reason the memory of his life and fame should be treasured by all as an example to the youth of our land to show that honor and fame may be earned in the school of philosophy as well as in the more tempting and active scenes of public life.

Many students, who at this moment are hard at work on their studies for the advantage of mankind, will feel themselves personally encouraged and honored by the tokens of respect and affection thus paid their prototype, Prof. Henry; and their stimulated labors in the cause of that science he loved so well will erect to him a monument more lasting than of brass or marble.

On January 17, 1879, Gen. Sherman was elected by the Board a member of the commission for erecting the National Museum building, and on March 7 he was chosen chairman of this commission.

"The office of member of this commission," he says in his first report, presented January 19, 1880, "has been by no means a sinecure, weekly meetings having been held with scarcely an interruption from the first organization."

The second report Gen. Sherman presented January 18, 1881, and the final report January 2, 1882. In the latter he "begs to refer to the important fact that, while a building is presented equal in every respect to what was anticipated - - - instead of incurring a deficiency, the fund has been so managed as to have to its credit an available balance of some thousands of dollars."

Gen. Sherman took a great interest in carrying into effect the act of Congress providing for a statue of Prof. Henry. He was active in inducing Congress to appropriate money to fireproof the east wing of the Smithsonian building, and he was elected January 17, 1883, by the Board with the chancellor and secretary upon a special commission "to act for and in the name of the Board in carrying into effect any act of Congress which might be passed providing for the erection of an additional building for the National Museum."

His second term as regent expired March 25, 1885, when he removed his residence to New York. He died February 14, 1891. For eleven years Gen. Sherman was diligent, active, attentive, and enthusiastic in his devotion to the Institution.

The detailed reports from the Bureau of Ethnology, the International Exchanges, the National Zoölogical Park, and the Library, and the report on the publications of the year are appended.

Respectfully submitted.

S. P. LANGLEY,
*Secretary.*

# APPENDIX TO SECRETARY'S REPORT.

## APPENDIX I.

### REPORT OF THE DIRECTOR OF THE BUREAU OF ETHNOLOGY FOR THE YEAR ENDING JUNE 30, 1891.

SIR: Ethnologic researches among the North American Indians were continued, under the Secretary of the Smithsonian Institution, in compliance with acts of Congress, during the year 1890-'91.

A report upon the work of the year is most conveniently presented under two general heads, viz, field work and office work.

#### FIELD WORK.

The field work of the year is divided into (1) archæology, and (2) general field studies, the latter being directed chiefly to religion, technology, and linguistics.

*Archæologic field work.*—At the close of the last fiscal year general exploration of the mound region was discontinued and the archæologic field work was placed in the charge of Mr. W. H. Holmes. During the summer of 1890 he began the work of archæological exploration in the Atlantic coast States. The ancient quarries of quartzite bowlders and of steatite within the District of Columbia were explored and extensive excavations were made. This work was continued throughout July, and in August a quarry site near the new U. S. Naval Observatory on a ridge overlooking Rock Creek Valley was examined. The phenomena observed upon this site were practically identical with those of Piny Branch described in the last annual report. A large area of the Potomac bowlder beds, 2 or 3 acres in extent, had been worked over to the depth of several feet by the aboriginal quarrymen and all available bowlders had been utilized in the manufacture of leaf-shaped blades. These were probably the blanks subsequently specialized as spear and arrow points, perforators, and similar instruments.

In August Mr. Holmes made a trip to the Mississippi Valley for the purpose of reexamining some mound groups not explored with sufficient care by the assistants before intrusted with that work. A week was spent in Grant County, Wis., mapping the remarkable groups of effigy mounds for which that region is noted. Subsequently he visited Pulaski County, Ark., and made a survey of the Knapp mounds at Toltec Station, whence he proceeded to the vicinity of Hot Springs, Ark., to examine the ancient novaculite quarries near that place. Apparently the early inhabitants had quarried this rock on an extensive scale and had used it in the manufacture of spear and arrow points and other articles. The pittings were on a large scale, even surpassing those of the District of Columbia quarries, and had generally been attributed by white settlers to Spanish gold hunters of an early period.

In September and October Mr. Holmes resumed his explorations in the District of Columbia and extended the work into the valley of the Potomac between Point of Rocks and Cumberland, Md., and into the Ohio Valley as far as Allegheny City. A trip was next made to the eastern shore of the Chesapeake, and a very interesting

Indian village site on the Choptank River, 2 miles below Cambridge, was examined. An ancient community of oyster dredgers had been established on a bluff about 20 feet above tide level. Subsequently this site was buried by wind-driven sand to the depth of 20 feet, and more recently the waves have encroached upon the land, exposing a section of the bluff and its buried village site. The most important feature of this exposure was the section of an ossuary or burial pit 12 feet in diameter and 5 feet deep, which had been dug upon the village site and filled with a mass of disconnected human bones, all of which were in an advanced state of decay. They were not accompanied by objects of art.

In April Mr. Holmes made a journey to Bartow County, Ga., and to Coahoma County, Miss., to make necessary observations of the great groups of mounds at these points. The principal Bartow County mound belongs to the group known as the Etowah group, and is a splendid example of the work of the unidentified builders. The shape of the great mound is that of a four-sided truncated pyramid but is not wholly symmetric. It is 63 feet high and measures about 175 feet across the nearly level top. The measurements of the four sides of the base are 380, 330, 360, and 350 feet. The slopes are steep, reaching in places 45°, and are broken by two decided eccentricities of configuration. On the south is a terrace from 40 to 50 feet wide, sloping to the base level of the mound at the east and ending in a nearly level platform about 45 feet square at the west end. This platform is about 20 feet lower than the mound and does not appear to have had means of communication with its summit. This irregular terrace has been called a roadway, but it has more the character of an addition to the great mound in process of construction. The other eccentricity alluded to is a graded way extending out to the east from the summit of the mound, and which to all appearances is the real roadway to the summit. This way is 20 or more feet in width, though somewhat broken down by erosion, and has a slope of only 21°. There can be little doubt that this mound was the stronghold of the village and that its top was inclosed by a stockade.

The Carson mounds in Coahoma County, Miss., form a group of unusual interest. There are four mounds of large size, two of them being oblong and with thin summits. The highest has an elevation of 25 feet. Scattered about these large mounds are nearly a hundred smaller ones from 1 to 6 feet in height and from 10 to 200 feet in diameter, most of which, as refuse indicates, represent house sites. The house floors have been of clay well smoothed on the upper surface and the walls and possibly the coverings have been of clay supported by a framework of canes. The clay has in many cases been basked, but whether from design in building or through the destruction of the structure by fire, is not easily determined. There are numerous large pits about the border of the site from which the earth used in building the mounds has been obtained. The area covered by the village is three-fourths of a mile long by half a mile wide.

In the spring of 1891 Mr. Holmes began the systematic exploration of the tide-water regions of Maryland and Virginia, which included a study of the art remains and of the phenomena of shell banks and village sites, as well as the mapping of all sites which have interest to the historian and the archæologist. In this work he was as sited by Mr. William Dinwiddie and for a short period by Mr. Gerard Fowke.

Through documentary evidence it is known that the tide-water region was occupied by tribes of Algonquian stock belonging to the Powhatan Confederacy. So thoroughly have they occupied this country that along the water courses nearly every available site bears evidence of occupation, and in the salt and brackish sections of the water courses shell banks—the kitchen-middens of this people—cover the shores in almost continuous lines. So numerous were the sites that a careful study of all was found to be impracticable, and it was determined to select for detailed examination a small number of those that are typical. On the Potomac the following localities have been chosen for a special study: The vicinity of the Little Falls, at the head of tide water; the site of Smith's town of "Nacotchtank," now Anacos-

tia; "Chapowamsie" Island at the mouth of the creek of that name; the site of the village of "Potowomeck" on Potomac Creek; the shell deposits of Goose Creek, a branch of Port Tobacco River; the great shell mounds of Pope's Creek, and the oyster dredging stations about the mouth of Wicomico River. Many sites upon the west shore of Chesapeake Bay and on the Patuxent River; also many village sites upon the James, most of them mentioned and located by Capt. John Smith, were visited and examined. These include "Chesapeac," on Lynnhaven Bay, Virginia, "Nansamund," on Chuckatuck Creek, west of Norfolk; Jamestown Island; "Chawopo," "Paspahegh," and "Quiyoughcohannock," near Clearmont; "Wennock," on Eppes Island, opposite City Point; and "Powhatan" just below Richmond. The art remains procured from these historic James River sites are identical in nearly every respect with the Potomac and Chesapeake relics, a fact which bears strongly upon the question of the unity of the art remains and the identity of the peoples of the tide-water country.

Mr. Gerard Fowke entered upon his duties as assistant archæologist on May 1, 1891. He began at once the exploration of the James River Valley, and at the close of the year was making excavations in an ancient cemetery near Gale, Allegheny County, Va. The object of that work, aside from the usual archæologic explorations, is to determine the western limits of areas occupied by the Algonquian tribes and the eastern limitations of the various groups of peoples belonging to the west.

As above mentioned, the field work upon mound explorations, which for several years had been under the charge of Prof. Cyrus Thomas, was discontinued except so far as was found necessary to correct some errors and supply some omissions. Mr. Henry L. Reynolds was the only one of the former assistants in the mound division who was retained. He was engaged during the early part of the last fiscal year in making examinations and resurveys of certain ancient works in Ohio, and in the spring of 1891 was sent to South Carolina to examine several important works in that State. Owing to severe illness, which terminated in his death (on April 17, 1891) while in the field, this last trip was unproductive of scientific results. By the death of Mr. Reynolds the Bureau has lost a skillful and industrious member, and archæology an enthusiastic student. For some time previous to his death, in addition to his other duties as assistant to Prof. Thomas, he had been engaged in preparing a paper on the prehistoric metallic articles of the mound area. The only other field work performed in relation to the mounds has been above explained. In order to assist Prof. Thomas in obtaining correct illustrations and plats of certain groups in Mississippi, Arkansas, and Wisconsin, which were deemed of more than ordinary importance in the study of the archæology of the mound region, Mr. Holmes visited those groups and made careful survey drawings of them, besides collecting important data concerning them.

Late in November Mr. Cosmos Mindeleff was ordered to proceed to the Casa Grande, on the Gila River, in Arizona, and examine that ruin with a view to its preservation as provided for by act of Congress, also to prepare plans and specifications and make contracts for the work. He was further directed to make an examination of the valley of the Rio Verde, and collect the data for a report upon the archæology of that region. Owing to unforeseen delays the contracts for the Casa Grande work were not executed until May 15, 1891, and were approved by the Secretary of the Interior late in June, but subsequently the time for the completion of the work was extended two months. It will be completed by October 1.

During his stay in the vicinity of the Casa Grande Mr. Mindeleff made surveys of the ruin proper and of the large ruin of which it forms a part, together with photographs, detailed plans, sketches, and notes, with a view to a detailed report. He found, among other results of his examination, that the ruin is now standing to within a very few feet of the height it had when built and occupied.

Pending the execution and approval of the contracts for the Casa Grande work, Mr. Mindeleff made an examination of the valley of the Rio Verde from its mouth

to Camp Verde and beyond. This region had never been thoroughly examined, and it was deemed highly probable that it would prove as rich in archæologic remains as the region about Camp Verde. Such, however, proved not to be the case. A chain of settlements was found extending from Camp Verde southward nearly to Fort McDowell, but the ruins are not so numerous as in the region immediately about Camp Verde. About 10 miles below the latter an extensive and well preserved group of cavate dwellings was found.

The buildings throughout the whole Verde Valley now in ruins were constructed of slabs of calcareous rock, or of river bowlders, or of both, and in their construction, location, and ground plans are affiliated with the northern type, rather than with the southern type, of which the best example is the Casa Grande on the Gila River. Data for a report upon the ruins in the valley of the Rio Verde, and upon the irrigating ditches and horticultural systems there pursued, were collected, and will be prepared for publication at once. Mr. Mindeleff remained in the field until after the close of the fiscal year.

*General Field Studies.*—Mrs. Matilda C. Stevenson remained at the Pueblo of Sia, New Mexico, from July to September 15, 1890. She was diligently engaged in completing her studies of the customs and mythology of the Sia Indians explained in the last annual report. Their cosmogony, and the rites of their secret cult societies, were made by her special subjects of investigation, with the view of securing a clearer understanding of their mythology and religious practices.

Dr. W. J. Hoffman, in July, visited the Menomonee Reservation at Keshena and the Ojibway Reservation at Lake Court Oreilles, Wis., the Ojibwa Reservation at La Point, and the Ottawa Indians at Petoskey, Mich. At Keshena he attended, by request of the Indians, the annual ceremony of the Mitawit or Grand Medicine Society, an order of shamans or priests professing the power of prophecy, exorcism of demons, the cure of disease, and the ability to confer success in the chase. The introductory portion of the ritual of initiation of this society embraces the dramatization of the Menomonee ideas of cosmogony and the genesis of mankind, the reception by the Indians from the Great Manito of the power of warding off disease and hunger, and instruction to candidates as to the proper mode of living, so as to gain admission into the realm presided over by Naqpote, the wolf, who is brother of Manabush, the mediator between the Menomonee and the Great Manito. The services of initiation of these ceremonies are preceded by a mortuary ritual lasting one entire night, in honor of the deceased member, whose place is filled later on by the initiation of a substitute.

Investigations were made at the Menomonee ceremony to compare it with a similar ritual found among the Ojibways. It appears that the Menomonee practices are offshoots from the Ojibway, and also that where the Ojibway shamans repeat certain phrases in an archaic form of language, as handed down to them, the Menomonee employ Ojibway words and phrases, perhaps to mystify the hearers, or perhaps because the ritual was obtained from the Ojibway in that form. The preparation of textile materials used in the manufacture of the several kinds of mats made by the Menomonee was also investigated and typical specimens were secured. Water color and other sketches were made to illustrate ceremonies, daily avocations, the aboriginal houses, grave boxes, and other objects of interest.

Upon the completion of his work at the above reservations, Dr. Hoffman proceeded to La Point to inquire of the Ojibway shamen concerning certain sacred birch-bark charts employed by them in the introduction of candidates into the society of shamans, and also to secure additional information relative to the explanation of pictographic cosmogony records. He then visited the Ottawa Indians on the eastern shore of Lake Michigan, near Mackinaw, to ascertain whether the ceremonies of the "Grand Medicine Society" were still practiced by them. This body of Indians professes to have discontinued these pagan rites, but assert that a band of the Ottawa, living farther south, near Grand Traverse, adheres to the primitive belief, and conducts its ceremonies annually.

Mr. James Mooney made a short visit in July to the mountain region of North Carolina and Tennessee, the former home of the Cherokees, for the purpose of collecting additional facts for his monograph upon that tribe. In connection with the same work he had intended to visit the Cherokee Nation in the Indian Territory in the following winter, but in the meantime the "Messiah religion" had begun to attract so much attention that he was directed to investigate that subject also at the same time, as well as to gather more material bearing upon the linguistic affinities of the Kiowa tribe. He left Washington December 22, and proceeding at once to the Cheyenne and Arapahoe Reservation in Indian Territory, where the ghost dances were in full progress, remained for several weeks studying the dance, making photographs, and collecting the songs used. This last was the most important part of the study, as most of the Messiah religion is embodied in songs many of which go to the root of Indian mythology. That religion is a remodeling of aboriginal beliefs as influenced by the ideas of Christianity lately imbibed from the white man, to be used for the utter confounding of the white man himself. It is in no sense a warlike movement. It is somewhat remarkable that the ghost songs in use by the various tribes are almost all in the language of the Arapahoes, the members of that tribe being the most active propagators of the new religion and their language being peculiarly adapted to music.

He then proceeded to the Kiowa Reservation, where linguistic and other materials were obtained, by which it may become possible to finally classify that hitherto isolated tribe. Additional ghost-dance material was also collected. After revisiting the Cherokee Nation, where several weeks were devoted to gathering information, especially in regard to the Indian geography of upper Georgia, he returned to Washington early in April.

In accordance with arrangements for the World's Columbian Exposition it was decided to make a tribal exhibit from one of the more primitive prairie tribes. The Kiowas were selected for the purpose and the work was assigned to Mr. Mooney, who at once prepared to return to their reservation. During May and June he collected a large variety of articles illustrative of the home life, arts, dress, and ceremonials of the tribe, and was still in the field at the close of the fiscal year.

## OFFICE WORK.

The Director during the year devoted all the time he could spare from other official duties to the completion of a work on the linguistic families of North America. His undertaking to classify the North American languages so as to be of scientific value as well as of practical use has been explained in previous reports. This classification is recognized to be, when properly made, an indispensable preliminary to all accurate ethnologic work relating to this continent. The essay, with its accompanying linguistic chart, was delivered to the Public Printer during the year, to form part of the seventh annual report of this Bureau, though that volume at this date has not yet been actually issued.

Col. Garrick Mallery, U. S. Army, during the year, when not occupied in special and occasional duties designated by the director, was engaged in arranging for publication the material gathered by him during several former years on the general theme of pictography. That title is used to embrace all modes of expressing and communicating thoughts and facts in a durable form without reference to sound. Such modes of expression being at one time if not still independent of oral language, the study of their history, evolution, and practice may assist in the solution of some ethnic and psychic problems, and may verify or modify some theories of anthropologic import. In the scheme of arrangement for publication the objective exhibition of mental concepts by the North American Indians has been classified with proper predominance, as it has exceeded in interest all others known which have not passed beyond the boundaries separating ideograms and emblems from syllabaries and alphabets. In order to promote explanation and comparison, however, copies

and descriptions of a large number of petroglyphs and other forms of pictographs found in Europe, Asia, Africa, Australia, and in many islands have been collated for the publication of selected and typical illustrations. With the same object, still more earnest attention has been directed to the synoptic presentation of illustrations from Mexico and Central and South America, as being presumably more closely connected than is the eastern hemisphere with the similar developments found in the present area of the United States, whether enduring on rocks with authorship unknown, or actually in current use among most of the Indian tribes. At the close of the fiscal year the treatise was substantially completed, the delay in its delivery to the Public Printer, as the contents of one of the forthcoming volumes in the series of annual reports of this Bureau, being occasioned by the preparation of the large number of illustrations required.

Mr. Henry W. Henshaw during the entire year devoted his time to administrative work and to continuing the preparation of the Dictionary of Indian Tribes, before explained in detail.

Prof. Cyrus Thomas was engaged during the year chiefly in the preparation of the second volume of his report on the archæology of the mound area of the United States, and other office work necessary in connection with the publication of a bulletin on the list of mound localities, the preparation of maps therefor, and of illustrations for the first volume of his report. When the whole manuscript was taken up for examination, preparatory to printing, its bulk was found to be too great for one volume. It was then decided to publish the part relating to mound localities in a bulletin. As this necessitated some change in the manuscript, the opportunity was embraced to incorporate the additional data which had been obtained. The bulletin was in print at the close of the year, though not yet issued.

Mr. W. H. Holmes included in his office work the preparation for the monographs of Prof. Cyrus Thomas of papers upon pottery, shell, textile fabrics, pipes, and other productions of the mound-building tribes, and the writing of reports upon the numerous explorations made during the year. These reports have been brought up to date and are on file. He has adopted the policy of preparing reports upon field work for file as the work proceeds, and his assistants are expected at the close of each separate piece of exploration or unit of study to make a report upon it of a sufficiently finished nature to serve the purpose of record and reference in case of their disability or separation from the office.

Rev. J. Owen Dorsey prepared the index to his monograph, The Ȼegiha Language-Myths, Stories, and Letters, and corrected the proof sheets of the second part of that volume. He resumed his work on the Ȼegiha-English dictionary, inserting many new words occurring in the texts and referring to each new word by page and line of the text. He devoted considerable time to the synonymy of the Athapascan, Caddoan, Kusan, Siouan, Takilman, and Yakonan families; comparing authorities, writing historical sketches of the tribes, gentes, and villages of those linguistic families, and rearranging all the material, in order to have it ready for printing. From December, 1890, to March, 1891, with the aid of a Kwapa delegate in Washington, he collected much information respecting the Kwapa or Quapaw tribe, a people closely related to the Omaha and Ponka, from whom they separated prior to 1540. Since March, 1891, he has been elaborating that material, which consists of about 150 personal names, arranged according to sex and gens, with the meaning of the name whenever attainable; over 3,500 entries for a Kwapa-English dictionary and several epistles and myths with grammatical and sociologic notes. This material will be of great assistance to him in the preparation of the Ȼegiha-English dictionary and other papers.

He also prepared for publication the following papers: A study of Siouan cults, illustrated with numerous sketches colored by Indians; Omaha and Ponka letters, containing the Ȼegiha epistles, which could not be published in Contributions to North American Ethnology, Vol. VI; an illustrated paper on Omaha dwellings, furniture, and implements; a paper on the social organization of the Siouan tribes.

Mr. Albert S. Gatschet during the fiscal year was engaged in office work only. After having completed the manuscript of the "Ethnographic Sketch" of his work, "The Klamath Indians of Southwestern Oregon," which was published during the year as Vol. II, Part I, of Contributions to North American Ethnology, he read the proof of it, which was completed in October, 1890. Since then he has been extracting, copying, and carding the vocabularies and other matter collected by him during the past ten years. This work is now accomplished concerning the Tonkawe, the Hitchiti, the Shawano, and Powhatan. That relative to the Creek, will soon be completed. A large number of personal tribal and vocal names of Indian origin were collected and partly explained in the intervals of the above work.

Dr. W. J. Hoffman continued the arrangement and classification of material relatting to the society of shamans of the Ojibwa Indians, which, together with numerous illustrations, was prepared for publication, and will form part of the Seventh Annual Report of the Bureau. This work will present from aboriginal records an exposition of the Ojibwa traditions of cosmogony and genesis and the dramatized ritual of the myths relating to the same. The musical notation of the songs and chants employed before and during the ceremonies of initiation, and copies of all of the birch-bark charts bearing the mnemonic characters relating to the ritual will be incorporated in the paper, together with the original texts. Dr. Hoffman has also been engaged in the elaboration of the data and sketches relating to the pictography and gesture language of the North American Indians, secured by him during previous field seasons.

Mr. James Mooney devoted the earlier part of the fiscal year to the elaboration of his Cherokee material, the first results of which, under the title of "Sacred Formulas of the Cherokees," will appear in the Seventh Annual Report of the Bureau. He also prepared a short descriptive catalogue of his previous ethnologic collections from the Cherokees, and began work on a paper contending that the South Atlantic States were formerly occupied by a number of Siouan tribes, if indeed that region was not the original home of the Siouan stock. In connection with this investigation a closer study of the linguistic material from the Catawban tribes of Carolina confirms the statement which has before been published by this Bureau, that they belonged to the Siouan family. Mr. Mooney also at intervals assisted on the Dictionary of Tribal Synonymy.

Mr. James C. Pilling has continued his bibliographic work throughout the fiscal year. At the date of the last report he was engaged in reading proof of the Bibliography of the Algonquian Languages. The volume is now ready for the press, and will include 614 pages and 82 full page illustrations, chiefly facsimiles of the title-pages of rare books, syllabaries, and other interesting bibliographic features. It is hoped that the work will be ready for distribution during the autumn of 1891. Among the special articles in it is one relating to the labors of "Apostle" Eliot among the Indians of Massachusetts, and more especially to his linguistic work. As this author was the earliest and the most noted of those engaged in this line of work, considerable space was devoted to him and his works, and it was thought proper to issue the article in separate form. It is noted below under the heading of Publications.

Mr. Pilling has ceased to be connected with the U. S. Geological Survey, being transferred to the Bureau of Ethnology, his appointment taking effect May 1, 1891. The stock or family of languages proposed to form the subject of his next bibliographic memoir is the Athapascan.

Mr. J. N. B. Hewitt has continued his work on the Tuskarora dictionary, the Tuskarora-English part being well advanced and the English-Tuskarora part commenced. Much material for the compilation of a complete grammar of the Tuskarora-Iroquoian tongue was added to that before acquired. For this object such anomalous, redundant, and defective verbs as have been recorded in the dictionary have been conjugated in all the derivative forms of which they are susceptible; a difficult but instructive task. Several regular verbs have also been conjugated to

develop all their known derivative forms. The number of possible derivative forms of a regular verb in the several conjugations is estimated by Mr. Hewitt to vary between 2,800 and 3,000. This numeration is of interest, because it has been asserted by students of Indian languages that the number of possible derivative forms of an American Indian verb is infinite, and, secondly, because it has been estimated that a Greek verb so conjugated would be represented by about 1,300 forms.

Grammatic gender has also received special attention. There are in the Tuskarora-Iroquoian tongue three genders, which Mr. Hewitt names the anthropic, the zoic, and the azoic, which are expressed through the prefix pronouns only. In the anthropic gender alone sex distinctions are found, and hence there are masculine and feminine pronouns therein. But in the zoic and azoic genders sex is not indicated. Hence, by the prefit pronouns the objects of discourse are classified into three genders.

Mr. Hewitt continued making translations from the old French writers, Perrot, Lafitau, La Potherie, and others, of the notices and accounts of the beliefs, rites, and ceremonies, superstitions, and mythic tales of Iroquoian peoples. These were collated as aids in explaining and elaborating the matter collected in the field personally by him. By their confirmative testimony, joined to the evidence of etymology, the Iroquoian cosmogony or genesis myth is found to originate in the personification by the Iroquoian mind of the elements, powers, processes, and the living creatures of the visible and sensible world.

Mrs. Matilda C. Stevenson was engaged from the latter part of September, 1890, to June 30, 1891, in preparing for publication the material collected at the Pueblo of Sia, New Mexico, during the preceding spring and summer.

Mr. Cosmos Mindeleff during the first five months of the fiscal year was occupied upon the card catalogue of ruins referred to in the last Annual Report and in the compilation and preparation of maps showing the distribution of ruins in the southwestern part of the United States. This work was temporarily discontinued late in November, when he was ordered into the field, as above explained.

He also has continued to be in charge of the modeling room. Its force during the year was devoted exclusively to the "duplicate series," reference to which has been made in previous reports, and no new work was undertaken. Five models were added to the series, ranging in size from 16 square feet to 250 square feet, and comprising the following subjects: Mummy Cave Cliff Ruin, Arizona; Pueblo of Walpi, Arizona; Pueblo of Sechumovi, Arizona; Ruin of Penasco Blanco, New Mexico; and Pit of Nelson Mound. This series is nearing completion, and the Bureau now has material sufficient to form the nucleus of an exhibit such as it is often called upon to make, without disturbing its series of original models now deposited in the National Museum. It has also a small number of models which can be drawn upon to supply the demand for such material in the way of exchange with colleges and other scientific institutions.

Mr. Jeremiah Curtin was occupied with office work exclusively during the year. From July 1, 1890, until February 1, 1891, he arranged and copied vocabularies which he had previously collected in California, namely, Hupa, Ehnikan, Weitspekan, Wintu, Yana and Palaihnihan. He devoted the later months of the year to classifying and copying a large number of myths which he had collected among the Hupa, Ehnikan and Wintu Indians. These myths are for the greater part connected with medicine, though some are creation myths and myths relating to religion and the origin of various tribal customs and usages.

Mr. De Lancey W. Gill continued in charge of the work of preparing and editing the illustrations for publications of the Bureau. The work done for the year ending June 30, 1891, was as follows:

| | |
|---|---|
| Drawings of objects and ethnologic specimens and miscellaneous diagrams... | 422 |
| Ancient ruins, earthworks, and landscape drawings.......................... | 133 |
| Maps ....................................................................... | 47 |
| Total ...................................................................... | 602 |

These drawings were prepared from field surveys and sketches, from photographs, and from the collections brought in by the ethnologists.

The photographic work remains under the able management of Mr. J. K. Hillers. Photographic negatives were secured from sittings of Indians representing the following tribes, viz: Sac and Fox, Senecas, Creek, and Cherokee. From these negatives 129 prints were furnished.

PUBLICATIONS.

The publications issued during the year are:

(1) Contributions to North American Ethnology, Volume II, Part I; The Klamath Indians of Southeastern Oregon, by Albert Samuel Gatschet, a quarto volume of cvi + 711 pages and map. This part includes an ethnographic sketch of the Klamath people, texts of the Klamath language, with explanatory notes, and a grammar of the Klamath language. The second part comprises the Klamath-English and English-Klamath dictionaries. It was in type at the end of the last fiscal year, but was not then received from the Public Printer.

(2) Bibliographic notes on Eliot's Indian Bible and on his other translations and works in the Indian language of Massachusetts. This is an abstract from a "Bibliography of the Algonquian Languages," by James Constantine Pilling, and forms pages 127–184 of the Algonquian Bibliography to be soon issued. As separately issued these "Notes" constitute a royal octavo pamphlet of 58 separately numbered pages. Two hundred and fifty copies were printed and issued.

It is with profound pleasure that attention is called to this abstract of the work of the officers of the Bureau during the term of a single year. By long training, by great zeal, and by deep scientific insight, these gentlemen are now able to accomplish results far beyond expectations when the Bureau was originally organized. The researches in this field have passed beyond the elementary stage, and the significance of the data being rapidly gathered becomes more and more apparent.

Very respectfully yours,

J. W. POWELL,
*Director, Bureau of Ethnology.*

Mr. S. P. LANGLEY,
*Secretary Smithsonian Institution.*

## APPENDIX II.

### REPORT OF THE CURATOR OF EXCHANGES FOR THE YEAR ENDING JUNE 30, 1891.

SIR: I have the honor to present the following brief statement of the operations of the Bureau of International Exchanges for the fiscal year ending June 30, 1891.

#### TABULAR STATEMENT OF THE WORK OF THE BUREAU.

The work done by the Bureau during the year is succinctly stated in the annexed table, prepared in a form similar to that adopted in preceding reports:

*Transactions of the Bureau of International Exchanges during the fiscal year 1890-'91.*

| Date. | Number of packages received. | Weight of packages received. | Ledger accounts. | | | | Domestic packages sent. | Invoices written. | Cases shipped abroad. | Letters received. | Letters written. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Foreign societies. | Domestic societies. | Foreign individuals. | Domestic individuals. | | | | | |
| 1890. | | *Lbs.* | | | | | | | | | |
| July | 9,107 | 28,799 | ...... | ...... | ...... | ...... | ...... | 1,238 | 122 | 201 | 170 |
| August | 4,214 | 13,643 | ...... | ...... | ...... | ...... | ...... | 964 | 37 | 157 | 102 |
| September | 5,693 | 15,968 | ...... | ...... | ...... | ...... | ...... | 1,447 | 65 | 141 | 136 |
| October | 12,144 | 28,842 | ...... | ...... | ...... | ...... | ...... | 1,327 | 67 | 207 | 238 |
| November | 5,375 | 12,670 | ...... | ...... | ...... | ...... | ...... | 1,577 | 62 | 182 | 239 |
| December | 4,507 | 23,568 | ...... | ...... | ...... | ...... | ...... | 1,926 | 101 | 166 | 157 |
| 1891. | | | | | | | | | | | |
| January | 10,749 | 23,566 | ...... | ...... | ...... | ...... | ...... | 1,444 | 91 | 164 | 317 |
| February | 8,220 | 21,258 | ...... | ...... | ...... | ...... | ...... | 2,630 | 85 | 165 | 151 |
| March | 4,616 | 15,253 | ...... | ...... | ...... | ...... | ...... | 1,902 | 60 | 229 | 199 |
| April | 5,150 | 13,727 | ...... | ...... | ...... | ...... | ...... | 1,862 | 46 | 168 | 174 |
| May | 13,350 | 22,396 | ...... | ...... | ...... | ...... | ...... | 1,072 | 78 | 195 | 259 |
| June | 7,451 | 18,122 | ...... | ...... | ...... | ...... | ...... | 4,444 | 148 | 232 | 285 |
| Total | 90,666 | 237,612 | 5,981 | 1,588 | 7,072 | 4,207 | 20,047 | 21,923 | 962 | 2,207 | 2,417 |
| Increase over 1889-'90 | 8,094 | 33,955 | 850 | 157 | 732 | 1,107 | 15,831 | 4,975 | 89 | 698 | 792 |

The rapid rate at which the Exchange work is growing is very plainly shown by a comparison of these figures with the similar ones of reports since 1886 in the table below:

| | 1886-'87. | 1887-'88. | 1888-'89. | 1889-'90. | 1890-'91. |
|---|---|---|---|---|---|
| Number of packages received | 61,940 | 75,107 | 75,966 | 82,572 | 90,666 |
| Weight of packages received | 141,263 | 149,630 | 179,928 | 202,657 | 237,612 |
| Ledger accounts: | | | | | |
| Foreign societies | 7,396 | 4,194 | 4,466 | 5,131 | 5,981 |
| Foreign individuals | | 4,153 | 4,699 | 6,340 | 7,072 |
| Domestic societies | 2,165 | 1,070 | 1,355 | 1,431 | 1,588 |
| Domestic individuals | | 1,556 | 2,610 | 3,100 | 4,207 |
| Domestic packages sent | 10,294 | 12,301 | 17,218 | 13,216 | 29,047 |
| Invoices written | 15,288 | 13,525 | 14,095 | 16,948 | 21,923 |
| Cases shipped abroad | 692 | 663 | 693 | 873 | 962 |
| Letters received | 1,131 | 1,062 | 1,214 | 1,509 | 2,207 |
| Letters written | 1,217 | 1,804 | 2,050 | 1,625 | 2,417 |

EXPENSES.

The expenses of the Exchange Bureau are met in part by direct appropriation from Congress and in part by appropriations made to Government Departments or Bureaus, either in the contingent funds or in specified terms for repayment to the Smithsonian Institution of a portion of the cost of transportation. To each of the Departments or Bureaus sending or receiving publications through the Smithsonian Institution a charge of 5 cents per pound weight is made under the authority of a resolution by the Board of Regents in 1878, this charge being necessary, as the appropriation made by Congress directly to the Institution for exchange purposes has never been sufficient to meet the entire cost of the work. For similar reasons it has been found necessary to make a charge of the same amount to State institutions, from which a further small amount has been received.

The direct appropriation by Congress for the year 1890-'91 was in the following terms:

For expenses of the system of International Exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries and compensation of all necessary employés, \$17,000.

The receipts and disbursements by the accounting officer of the Smithsonian Institution on account of International Exchanges, dated July 1, 1891, for the preceding fiscal year, were as follows:

RECEIPTS.

| | |
|---|---|
| Direct appropriation by Congress | \$17,000.00 |
| Repayments to the Smithsonian Institution from United States Government Departments | 3,361.12 |
| State institutions | 9.95 |
| Total | 20,371.07 |

DISBURSEMENTS.

| | From Congressional appropriations. | Repayments. |
|---|---|---|
| Salaries and compensation | $14,159.46 | |
| Freight | 1,298.33 | |
| Packing boxes | 758.16 | |
| Printing | 189.05 | |
| Postage | 184.58 | |
| Stationery | 410.42 | |
| Incidentals | ............ | |
| | 17,000.00 | $3,382.21 |

The above table shows that the entire amount received from Government Bureaus was $3,371.07, making the sum practically appropriated $20,371.07. Previous reports have pointed out the desirability of combining in a single item the various appropriations for the Exchange service, now divided in comparatively small sums among several of the large appropriation bills. For the year 1890-'91 an estimate for the entire expense of the service of $29,500* was submitted, this sum being intended to include these smaller amounts alluded to and also an item of $2,000 to cover the expense of an immediate exchange of Parliamentary documents with the countries entering into the treaty of Brussels of 1886, as well as to provide for a proper compensation to several of the larger steamship companies for transportation of freight, a service now performed without charge. The amount appropriated was $17,000, an increase of $2,000 over that of the preceding fiscal year.

CORRESPONDENTS.

The name of each correspondent of the Bureau, whether society, institution, or individual, is entered upon a large card, which shows all packages received at the Bureau for the person or institution and also the packages sent to the Bureau for distribution. These cards have now accumulated to the number of 18,848, divided into foreign societies, foreign individuals, domestic societies, and domestic individuals. The individuals that have died and the societies that have ceased to exist are still retained for convenience of reference in the same file.

| | Foreign. | Domestic. |
|---|---|---|
| Societies and institutions | 5,981 | 1,588 |
| Individuals | 7,072 | 4,207 |
| Total | 13,053 | 5,795 |

A comparison with similar figures for 1889-'90 shows a total increase of 2,846 cards.

INTERNATIONAL EXCHANGE OF OFFICIAL DOCUMENTS.

Under the treaty, the text of which was given in full in Dr. Kidder's Report on Exchanges for the year 1887-'88, the exchange of the official publications of the United States Government with the other Governments adhering to the treaty, is conducted through the Smithsonian Institution Bureau of International Exchanges.

* See report of the Secretary of the Smithsonian Institution, 1890, pages 18and 19.

and this, together with the transmission abroad of the publications of the various departments or bureaus of the Government, now forms a very large proportion of the Bureau's work.

The entire number of publications sent abroad during the year, under the provision of the act of Congress of March 2, 1867, was 20,683, and there have been received in return 8,836 packages or volumes. The United States Government Departments have forwarded to their correspondents abroad through the Bureau 20,041 packages, and have received in return 11,764 packages. The total then of the exchanges on Government account has been 20,600 packages received, and 40,724 sent abroad, a total of 61,324 packages or 67.75 per cent of the total number handled. This exchange on account of the Government Bureaus is shown in detail in the following table:

*Statement of governmental exchanges distributed during the year 1890–'91.*

| | Packages. | | | Packages. | |
|---|---|---|---|---|---|
| | Received for. | Sent by. | | Received for. | Sent by. |
| American Ephemeris | 2 | ........ | National Board of Health | 2 | ........ |
| Army Medical Museum | 1 | ........ | Nautical Almanac | 20 | 188 |
| Astrophysical Observatory | 44 | 1 | Navy Department | 6 | ........ |
| Attorney-General | 1 | ........ | Office of Indian Affairs | 5 | ........ |
| Board of Indian Commissioners | 1 | ........ | Office of Chief of Engineers | 38 | 70 |
| Bureau of Education | 70 | 10 | Ordnance Bureau, U.S. Army | 3 | ........ |
| Bureau of Ethnology | 95 | 11 | Post-Office Department | 1 | ........ |
| Bureau of Exchanges | 7 | 15 | Public Printer | ........ | *24,050 |
| Bureau of Medicine and Surgery | 2 | ........ | Smithsonian Institution (assigned) | ........ | 314 |
| Bureau of Navigation | 3 | ........ | Smithsonian Institution, mail | 7,344 | ........ |
| Bureau of Ordnance, U.S.Navy | 1 | ........ | Smithsonian Institution | 2,273 | 8,407 |
| Bureau of Rolls, State Department | 1 | ........ | Smithsonian Institution, return packages | 46 | ........ |
| Bureau of Statistics | 32 | ........ | Soldiers' Home | 1 | ........ |
| Bureau of Mint | 3 | ........ | Surgeon-General's Office | 146 | 580 |
| Census Office | 5 | ........ | President of the United States | 1 | ........ |
| Commissioners of the District of Columbia | 2 | ........ | Botanic Garden | 2 | 3 |
| Comptroller of the Currency | 2 | ........ | U.S. Coast Survey | 69 | 37 |
| Department of Agriculture | 120 | 880 | U.S. Commission of Weights and Measures | 1 | ........ |
| Department of Interior | 16 | 102 | U.S. Entomological Commission | 5 | ........ |
| Department of Labor | 17 | 19 | U.S. Fish Commission | 51 | 261 |
| Department of State | 14 | 1 | U.S. Geological Survey | 414 | 3,370 |
| Department of War | 15 | 223 | U.S. National Museum | 299 | 2,138 |
| General Land Office | 5 | ........ | U.S. Naval Observatory | 119 | 2,149 |
| House of Representatives | 1 | ........ | U.S. Patent Office | 38 | 487 |
| Hydrographic Office | 60 | ........ | U.S. Signal Office | 90 | 240 |
| "Index Medicus" | 2 | ........ | U.S. Treasury Department | 7 | 1 |
| Interstate Commerce Commission | ........ | 6 | | 20,600 | 44,091 |
| Library of Congress | 8,836 | ........ | Total | 64,691 | |
| Light-House Board | 2 | 1 | | | |
| National Academy | 269 | 527 | | | |

* This figure represents fifty sets of the official publications of the United States Government received from the Public Printer. Forty-three sets are now distributed under the law, and thus the total number of packages distributed experiences a reduction of 3,369, leaving as a total 61,324 packages.

Adding the miscellaneous exchanges to the total of Government exchanges, the total is 90,666 packages. Of this number 61,619 were received for foreign and 29,047 for domestic distribution.

The Government of Paraguay, the first to carry out the provisions of the treaty of Brussels for the immediate exchange of parliamentary annals, began at the end of June, 1890, the regular transmission of the Official Journal and the Gazette of the Paraguay Congress. Pending the passage by Congress of a bill making special provision to enable the Institution to carry out this treaty, as the recognized Exchange Bureau of the United States Government, no return for this exchange has yet been made. A bill appropriating $2,000 for the purpose named passed the Senate at the last session, but failed to reach consideration in the House of Representatives.

It is gratifying to note that on July 25, 1890, announcement was made of the establishment by the Government of New South Wales of a special board for receiving and transmitting International Exchange publications. The exchange with that country has heretofore been effected through the Royal Society of New South Wales.

Notice was also received of the establishment by the Government of Uruguay on December 10, 1890, of an Exchange Bureau designated as the Oficina de Deposito, Reparto y Canje Internationales.

### EFFICIENCY OF THE SERVICE.

The recommendation for an additional assistant in the shipping room having received your approval by the transfer in October, 1891, of Mr. George L. Snider from the Smithsonian to the exchange roll, it is believed that the exchange work at the close of the fiscal year was in more satisfactory condition than ever before. Eight thousand and ninety-four more packages were handled than in the previous year, an increase of 10.2 per cent, and on June 30, 1891, all that could be disposed of had been shipped, leaving but 153 packages then on hand.

Packages received from abroad for distribution in the United States are sent out by registered mail, a record being made of each package showing the sender and the person or institution addressed. As a rule, this record can be made, the package can be rewrapped in stout paper and can be delivered at the post-office on the day, or within one or two days of its receipt. In some instances where the Bureau is crowded by the receipt of several thousand Government documents, a little longer delay may take place.

Books for distribution abroad received from individuals or institutions in the United States are entered in a similar way and are held until a sufficient number have accumulated to make a reasonable shipment to any one country. They are then carefully examined and a list for each country is made up and the volumes packed and shipped. Where a large number of packages for one country are received from any institution they are usually shipped with a delay of from one to four or five days.

An improvement in foreign transmissions has been made in the Exchange Office by increasing the frequency of shipments. The number of shipments to each country and the date of shipment is given in Exhibit A appended, but the great need at present is a more rapid communication with the principal European countries. This can only be effected when the appropriation by Congress becomes sufficient to enable the institution to pay for fast freight. As it is now, free freight is granted by a majority of the steamship companies, and where it is necessary to pay for transportation, the boxes must be sent by slow steamers offering low rates.

Dr. Felix Flügel in Leipzig, and Messrs. William Wesley & Son, in London, the foreign agents of the Institution, have paid the same careful attention to its interests as in former years. I regret to note here the death of the senior member of the firm of William Wesley & Son, which occurred on April 17, 1891. I also have to note the death of Dr. Felipe Poey on January 28, 1891. Dr. Poey has taken charge of the

Smithsonian exchanges in Cuba since 1876, and his son, Dr. Frederic Poey, has kindly offered to continue the work.

Grateful acknowledgments are also due to the following transportation companies and firms for their continued liberality in granting free freight, or in otherwise assisting in the transmission of exchange parcels and boxes, while to other firms we are indebted for greatly reduced rates, in consideration of the disinterested services of the institution in the diffusion of knowledge.

LIST OF SHIPPING AGENTS GIVING FREE FREIGHT.

Allan Steamship Company (A. Schumacher & Co., agents), Baltimore.
d'Almeirim, Baron, Royal Portuguese consul-general, New York.
American Board of Commissioners for Foreign Missions, Boston.
American Colonization Society, Washington, District of Columbia.
Anchor Steamship Line (Henderson & Bro., agents), New York.
Atlas Steamship Company (Pim, Forwood & Co.), New York.
Bailey, H. B., & Co., New York.
Barber & Co., New York.
Bixby, Thomas E., & Co., Boston.
Borland, B. R., New York.
Bors, C., consul-general for Sweden and Norway, New York.
Botassi, D. W., consul-general for Greece, New York.
Boulton, Bliss & Dallett, New York.
Calderon, Climaco, consul-general for Colombia, New York.
Caldo, A. G., consul-general for Argentine Republic, New York.
Cameron, R. W., & Co., New York.
Baltazzi, X., consul-general for Turkey, New York.
Compagnie, Générale Transatlantique (A. Forget, agent), New York.
Cunard Royal Mail Steamship Company (Vernon H. Brown & Co., agents), New York.
Dennison, Thomas, New York.
Espriella, Justo R. de la, consul-general for Chile, New York.
Florio Rubattino Line—Navigazione Generale Italiano (Phelps Bros. & Co.), New York.
Grace, W. R., & Co., New York.
Hamburg American Packet Company (R. J. Cortis, manager), New York.
Hensel, Bruckmann & Lorbacher, New York.
Inman Steamship Company (Henderson & Bro., agents), New York.
Mantez, José, consul-general for Uruguay, New York.
Merchant, S. L., & Co., New York.
Muñoz y Espriella, New York.
Murray, Ferris & Co., New York.
Navarro, J. N., consul-general for Mexico, New York.
Netherlands American Steam Navigation Company (W. H. Vanden Toorn, agent), New York.
New York and Brazil Mail Steamship Company, New York.
New York and Mexico Steamship Company, New York.
North German Lloyd (agents: Oelrichs & Co., New York; A. Schumacher & Co., Baltimore).
Obarrio, Melchor, consul-general for Bolivia, New York.
Pacific Mail Steamship Company (H. J. Bullay, superintendent), New York.
Panama Railroad Company, New York.
Pioneer Line (R. W. Cameron & Co.), New York.
Perry, Ed., & Co., New York.
Pomares, Mariano, consul-general for Salvador, New York.
Red Star Line (Peter Wright & Sons, agents, New York and Philadelphia).
Royal Danish consul, New York.

Royal Spanish consul, New York.
Ruiz, Domingo L., consul-general for Ecuador, New York.
Stewart, Alexander, consul-general for Paraguay, Washington, District of Columbia.
Toriello, Enrique, consul-general for Guatemala, New York.
Vatable, H. A., & Co., New York.
White Cross Line of Antwerp (Funch, Edye & Co.), New York.
Wilson & Asmus, New York.

LIST OF THE FOREIGN CORRESPONDENTS OF THE SMITHSONIAN INSTITUTION ACTING AS ITS AGENTS FOR THE INTERNATIONAL EXCHANGES.

Algeria: Bureau Français des Echanges Internationaux, Paris, France.
Austria-Hungary: Dr. Felix Flügel, No. 1, Robert Schumann, Leipzig, Germany.
Brazil: Biblioteca Nacional, Rio Janeiro.
Belgium: Commission des Echanges Internationaux, Rue du Musée, No. 5, Bruxelles.
British America: McGill College, Montreal, or Geological Survey Office, Ottawa.
British Colonies: Crown Agents for the Colonies, London, England.
British Guiana: The Observatory, Georgetown.
Cape Colony: Agent-general for Cape Colony, London, England.
China: Dr. D. W. Doberck, government astronomer, Hong Kong; for Shanghai: Zi-ka-wei Observatory, Shanghai.
Chili: Museo Nacional, Santiago.
Colombia (U. S. of): National Library, Bogotá.
Costa Rica: Biblioteca Nacional, San José.
Cuba: Dr. Frederick Poey, Calle del Prado, 29.
Denmark: Kong. Danske Videnskabernes Selskab, Copenhagen.
Dutch Guiana: Surinaamsche Koloniaale Bibliotheek, Paramaribo.
East India: Secretary to the Government of India, Calcutta.
Ecuador: Observatorio del Colegio Nacional, Quito.
Egypt: Institut Egyptien, Cairo.
France: Bureau Français des Echanges Internationaux, Paris.
Germany: Dr. Felix Flügel, No. 1, Robert Schumann Strasse, Leipzig.
Great Britain and Ireland: William Wesley & Son, 28 Essex Street, Strand, London.
Greece: United National and University Library, Athens.
Guatemala: Instituto Nacional de Guatemala, Guatemala.
Guadeloupe: (Same as France.)
Haiti: Sécrétaire d'état des relations extérieures, Port-au-Prince.
Island: Islands Stiptisbokasáfn, Reykjavík.
Italy: Bibliotheca Nazionale Vittorio Emanuele, Rome.
Japan: Minister of Foreign Affairs, Tokio.
Java: (Same as Holland.)
Liberia: Liberia College, Monrovia.
Madeira: Director-General, Army Medical Department, London, England.
Malta: (Same as Madeira.)
Mauritius: Royal Society of Arts and Sciences, Port Louis.
Mozambique: Sociedad de Geografía, Mozambique.
Mexico: Packages sent by mail.
New Caledonia: Gordon & Gotch, London, England.
Newfoundland: Postmaster-General, St. Johns.
New South Wales: Government Board for International Exchanges.
Netherlands: Bureau Scientifique Central Néerlandais, Den Helder.
New Zealand: Colonial Museum, Wellington.
Norway: Kongelige Norske Frederiks Universitet, Christiania.
Paraguay: Government, Asuncion.
Peru: Biblioteca Nacional, Lima.

**Philippine Islands:** Royal Economical Society, Manila.
**Polynesia:** Department of Foreign Affairs, Honolulu.
**Portugal:** Biblioteca Nacional, Lisbon.
**Queensland:** Government Meteorological Observatory, Brisbane.
**Roumania:** (Same as Germany.)
**Russia:** Commission Russe des Echanges Internationaux, Bibliothèque Impériale Publique, St. Petersburg.
**St. Helena:** Director-General, Army Medical Department, London, England.
**San Salvador:** Museo Nacional, San Salvador.
**Servia:** (Same as Germany.)
**South Australia:** General Post-Office, Adelaide.
**Spain:** R. Academia de Ciencias, Madrid.
**Sweden:** Kongliga Svenska Vetenskaps Akademien, Stockholm.
**Switzerland:** Eidgenossensche Central Bibliothek, Bern.
**Tasmania:** Royal Society of Tasmania, Hobarton.
**Turkey:** Bibliothèque Générale Ottomane, Constantinople.
**Uruguay:** Oficina de Depósito, Reparto y Canje Internacional, Montevideo.
**Venezuela:** University Library, Caracas.
**Victoria:** Public Library, Museum, and National Gallery, Melbourne.

The system of recording the correspondence of the Bureau adopted on January 1, 1890, has continued to give satisfaction. A further improvement in keeping the record of packages received has been effected by adopting as a substitute for the blotter and day book heretofore in use a record upon separate sheets of paper, which are subsequently bound up as a day book and upon which a record is made of all packages received. The packages to or from each institution or individual are then entered from these sheets upon the ledger cards. The system has the advantages that several persons can work upon the sheet at the same time, and that no copying of the record is required, introducing errors and requiring much time. This form of day-book sheet was adopted on January 1, 1891. A further duplication of record books is avoided by having the authorized officer of the Smithsonian Institution, National Museum, Bureau of Ethnology, U. S. Geological Survey, and the U. S. Fish Commission acknowledge the receipt of packages addressed to their offices directly upon these sheets.

A new edition of the list of foreign correspondents of the Bureau is urgently needed to facilitate current work. The list now in use was printed in 1885, since which time the list has doubled in number.

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## Exhibit A.

### TRANSMISSION OF EXCHANGES TO FOREIGN COUNTRIES.

**Argentine Republic:** October 2, November 6, 1890; January 19, April 17, June 22, 1891.
**Austria-Hungary:** Included in transmissions to Germany.
**Belgium:** July 17, September 5, October 1, November 3, December 5, 19, 1890; January 15, February 18, March 9, May 15, June 20, 22, 1891.
**Bolivia:** September 10, 1890; June 22, 1891.
**Brazil:** July 14, October 16, November 6, 1890; January 19, April 17, June 22, 1891.
**British Colonies:** Included in transmissions to England.
**China:** November 7, 1890; June 24, 1891.
**Chile:** November 6, 1890; January 19, June 22, 1891.
**Colombia, United States of:** September 10, November 6, 1890; June 22, 1891.

Costa Rica: March 28, June 26, 1891.

Cuba: June 26, 1891 (also by mail).

Denmark: August 16, November 3, December 9, 1890; January 15, March 6, June 6, 23, 1891.

Dutch Guiana: June 22, 1891.

East India: Included in transmissions to England.

Ecuador: September 10, 1890; June 22, 1891.

Egypt: September 10, 1890; June 26, 1891.

France: July 17, August 8, September 4, 20, October 14, 31, November 19, 24, December 5, 19, 27, 1890; January 13, February 6, 18, March 6, 24, April 8, 21, May 4, 22, June 3, 13, 20, 24, 30, 1891.

Germany: July 17, 28, August 28, September 23, October 7, 23, November 5, 11, 20, 28, December 5, 19, 23, 1890; January 10, 22, February 3, 5, 14, March 6, 23, April 8, 22, May 2, 19, June 3, 10, 20, 23, 30, 1891.

Great Britain and Ireland: July 17, 25, September 2, 13, 24, October 6, 13, 29, November 8, 17, 21, December 2, 8, 19, 29, 1890; January 10, 24, February 10, 24, March 3, 18, April 2, 25, May 6, 21, June 4, 12, 20, 24, 1891.

Greece: April 19, June 26, 1891.

Guatemala: June 26, 1891.

Italy: July 17, August 25, September 11, 29, October 31, November 24, December 9, 19, 1890; January 8, 19, February 12, 24, April 7, 28, June 5, 20, 23, 1891.

Japan: August 6, September 30, November 7, December 9, 1890; January 8, March 9, May 10, June 24, 1891.

Liberia: June 26, 1891.

New South Wales: August 6, November 8, December 8, 1890; March 9, May 8, June 24, 1891.

Netherlands: July 17, September 6, November 4, December 19, 1890; January 14, February 14, March 3, May 29, June 20, 24, 1891.

New Zealand: August 6, September 13, October 13, November 8, December 8, 1890; January 8, March 9, May 8, June 24, 1891.

Nicaragua: June 26, 1891.

Norway: July 17, September 11, 1890; March 2, June 1, 24, 1891.

Peru: September 10, November 6, 1890; June 22, 1891.

Polynesia: June 24, 1891.

Portugal: July 17, September 11, 1890; January 13, March 5, June 8, 24, 1891.

Queensland: August 6, September 13, November 8, December 8, 1890; March 9, May 8, June 24, 1891.

Roumania: Included in transmissions to Germany.

Russia: July 17, September 6, October 31, November 11, December 19, 1890; January 8, February 6, 14, 28, April 14, 30, May 28, June 20, 24, 1891.

Servia: Included in transmissions to Germany.

San Salvador: June 24, 1891.

South Australia: August 6, November 8, 1890; March 9, June 24, 1891.

Spain: September 8, December 9, 1890; January 13, February 26, June 24, 1891.

Sweden: July 17, September 8, October 30, November 5, 1890; February 27, April 11, May 16, June 24, 1891.

Switzerland: July 17, September 10, November 4, December 9, 19, 1890; January 19, 22, February 14, March 7, April 13, June 1, 24, 1891.

Tasmania: September 13, December 8, 1890; March 9, June 24, 1891.

Turkey: April 10, June 26, 1891.

Uruguay: November 6, 1890; June 22, 1891.

Venezuela: September 10, November 6, 1890; June 22, 1891.

Victoria: August 6, October 31, November 8, December 8, 1890; March 9, May 8, June 24, 1891.

In addition to the above, shipments of United States Congressional publications were made on October 11, 1890, January 8, May 15, 1891, to the governments of the following-named countries:

Argentine Republic.
Austria.
Baden.
Bavaria.
Belgium.
Buenos Ayres.
Brazil.
Canada (Ottawa).
Canada (Toronto).
Chile.
Colombia, United States of.
Denmark.
France.
Germany.
Great Britain.
Greece.
Haiti.
Hungary.
India.
Italy.
Japan.
Mexico.*
Netherlands.
New South Wales.
New Zealand.
Norway.
Peru.
Portugal.
Prussia.
Queensland.
Russia.
Saxony.
South Australia.
Spain.
Sweden.
Switzerland
Tasmania.
Turkey.
Venezuela.
Victoria.
Wurtemberg.

The distribution to foreign countries was made in 962 cases, representing 393 transmissions, as follows:

| | | | |
|---|---|---|---|
| Argentine Republic | 8 | Japan | 11 |
| Austria † | 3 | Liberia | 1 |
| Baden † | 3 | Mexico § | 3 |
| Bavaria † | 3 | New South Wales | 9 |
| Belgium | 15 | Netherlands | 13 |
| Bolivia | 2 | New Zealand | 12 |
| Buenos Ayres | 3 | Nicaragua | 1 |
| Brazil | 9 | Norway | 8 |
| British Colonies ‡ | .. | Peru | 6 |
| Canada § | 6 | Polynesia | 1 |
| China | 2 | Portugal | 9 |
| Chile | 6 | Prussia † | 3 |
| Colombia (United States of) | 6 | Queensland | 10 |
| Costa Rica | 2 | Roumania † | .. |
| Cuba § | 1 | Russia | 18 |
| Denmark | 10 | Saxony † | 3 |
| Dutch Guiana | 1 | Servia † | .. |
| East Indies | 3 | San Salvador | 1 |
| Ecuador | 2 | South Australia | 7 |
| Egypt | 2 | Spain | 8 |
| France | 28 | Sweden | 11 |
| Germany | 32 | Switzerland | 15 |
| Great Britain | 32 | Tasmania | 7 |
| Greece | 5 | Turkey | 5 |
| Guatemala | 1 | Uruguay | 2 |
| Haiti | 3 | Venezuela | 5 |
| Hungary † | 3 | Victoria | 10 |
| Italy | 20 | Wurtemberg † | 3 |

Very respectfully, your obedient servant,

W. C. WINLOCK,
*Curator of Exchanges.*

Mr. S. P. LANGLEY,
*Secretary Smithsonian Institution.*

*Transmissions to Mexico have been suspended temporarily.
† Miscellaneous exchanges included in transmissions to German,
‡ Miscellaneous exchanges included in transmissions to Great Britain
§ In addition to a large number sent by mail.

## Appendix III.

### REPORT OF THE ACTING MANAGER OF THE NATIONAL ZOOLOGICAL PARK.

SIR: I have the honor to submit the following report of the operations of the National Zoological Park for the fiscal year ending June 30, 1891.

At the opening of the year the land for the park was not yet all acquired. Steps were taken to expedite the final acquisition as much as possible, yet it was not until November 4, 1890, that possession was finally obtained of the entire tract.

In the mean time arrangements were made to repair the old Holt mansion, situated upon the left bank of the creek, in such a manner as to fit it for occupation as an office for the park. The old building was found to require much more extensive repairs than were anticipated. It is a long, low structure, built rather for coolness and country retirement than for purposes of business activity; and the walls, although thick, were found to be cracked and crumbling, and the foundations to be highly insecure. Before anything else could be done several of the walls had to be replaced and new foundations laid. This consumed the greater part of the appropriation and it was only possible to finish two rooms to be occupied as an office. A small barn with stable was built near the house for the accommodation of the horses required for the park service.

An inclosure of the park being found imperatively necessary, a design for a fence was made by Mr. W. R. Emerson and this was erected as fast as the land was finally acquired by the United States. It is of stout, unpainted, oak palings, intended not so much to regulate the movements of the public as to keep out dogs and animals injurious to the creatures in the inclosure.

As a preliminary to the laying out of roads and selecting sites for buildings, Mr. D. J. Howell was employed to make an accurate topographical survey of the park. The topographical work of the Coast Survey was used as a basis for this, the contours being carefully corrected and the highest levels reached by the water in Rock Creek being noted wherever it was possible to ascertain them.

For reasons of economy it was thought best to lay out for the present but a single road, which should cross Rock Creek on a continuation of the so-called Quarry road, which lies mainly outside the gates. This main road within the park was staked out to a width of 30 feet, and has been carefully graded and macadamized for a distance of some 3,000 feet from the entrance. Beyond this a road, formerly a cart track, leads through the park to the western boundary, and has been somewhat improved for its entire length to afford some partial access for carriages in this direction.

The "creek," so called (which it will be remembered is really a quick-running stream), is ordinarily fordable at a point near that where the road crosses, but this ford is impassable in times of flood, and extraordinary precautions had to be taken to secure a crossing above high-water mark, the narrowness of the stream and the precipitous character of the surrounding hills which it drains making it necessary to provide for a rise of at least 15 feet. Thus a "fill" of considerable extent was required on both approaches to the bridge, a condition that greatly increased the expense and labor of making the road.

Measures were at once taken to erect a bridge suitable for foot passengers and carriages. Several plans for such a structure were submitted, examined and rejected,

mainly because of the great cost which their execution would entail. A plan prepared by Mr. D. J. Howell was finally selected as being effective for the purpose required at a minimum of expense. It is a combined iron and wooden structure, 128 feet in length, resting upon two granite piers and two abutments. The plans were carefully examined, and criticised by skilled experts, and were believed by competent engineers to be sufficient to withstand any flood likely to occur. At the close of the fiscal year the piers and abutments had been completed, but the superstructure was not yet in place.

The quarry near the entrance to the park seemed admirably fitted for the construction of dens and yards for bears. In order to ascertain its condition, it was cleared of a great quantity of loose earth and rock which had fallen from the cliffs above. The quarry face was found to be in most places sufficiently steep to prevent the bears from climbing it, and where this was not the case the necessary steepness was obtained by blasting. To afford shelter for the bears spacious dens in which shelves were fashioned were hollowed out from the face of the rock, and in front of these there was built a strong iron fence 10 feet in height inclosing yards of considerable extent. The upper ends of the vertical bars of the fence were pointed and turned inward to prevent the escape of the bears, the floor of the yards was smoothly cemented, and a large basin, supplied with running water, built in each. Work upon these yards has been frequently interrupted by the falling from the slopes of large quantities of earth and rock. To obviate this Mr. Olmsted, the landscape gardener, has advised that a retaining wall be built at the top of the cliffs. But, as elsewhere stated, the park boundary runs at the upper edge of these cliffs and only a partial control of the difficulties can be obtained unless the park property is extended here some yards further back. The system of yards as projected includes three principal inclosures and a smaller one to be used as a shifting pen. At an early day this system will have to be enlarged, as the park has now four species of bears and one subspecies.

The brow of the first hill overlooking the bridge was selected as a site for a house for animals requiring heat. The design for this house, furnished by Mr. Emerson, was somewhat modified to suit the exigencies of the appropriation available, it being found impracticable to erect more than a portion of the structure. The house is of stone, a handsome gneiss, quarried upon Broad Branch some 2½ miles from the park. Its plan shows a long corridor upon one side of which are arranged the cages for large animals. Exterior yards and an extension for the accommodation of smaller animals will be added if funds are appropriated for that purpose. At present the house is much overcrowded and the animals are not suitably accommodated.

Accommodations for the small herd of bison were early considered. It seemed desirable to place these animals where they could have considerable range. When confined even in large yards they cut up the ground so much that they soon destroy every vestige of grass or other green thing. Still, if the inclosures are too large the animals keep so far away as not to be seen at all by the public. A site was selected in a protected locality on a hillside where small paddocks could be made along the main road and larger yards for grazing grounds could be carried from these down into the rich bottomland along Rock Creek, where abundance of grass is naturally produced. Here there was constructed a barn for the buffalo, which is a novel and picturesque structure of black-oak logs admirably harmonizing with the location. The appropriation was so limited that it was found necessary to place the elk also in this barn, and paddocks for them were accordingly built adjoining it. Inexpensive but strong fences for these paddocks were made of iron rods running horizontally through rough cedar posts and coupled together at the ends. Some difficulty has been found with the elk fence which has not stood the continuous battering given it by the males during the rutting season as well as was expected. The original plan of extending the paddocks to the bottom land of the creek will shortly be carried out.

Paddocks for the deer and antelope have been constructed on the left bank of the

creek along the eastern boundary of the park. This situation is admirably adapted by nature for the animals, but has the disadvantage of exposing them to the sight of dogs both on the outside of the park and within it. Three animals have been so frightened as to lose their lives from this cause, and it will be necessary to make the fence so tight as to entirely prevent the sight of dogs and probably it will be advisable to exclude them from this part of the park altogether.

The unexpected gift of an Asiatic elephant by Mr. James E. Cooper made it necessary to hastily prepare a barn. This is a temporary structure, but will be so fitted as to serve for shelter during the winter. It was prepared for but one animal, but by Mr. Cooper's generosity a second elephant was lent to the park, and the two have been made comfortable within it. The situation of this barn is not wholly satisfactory. At the time it was built it was thought desirable to place it at a considerable distance from the boundaries of the park in view of the possibility of the animals becoming unmanageable. These apprehensions were fortunately not well-founded, and it would be much more convenient to have the elephants nearer the stream so that they could frequently have immediate access to the water. If funds for the erection of a permanent elephant house should become available this matter will no doubt be considered. The expense of the maintenance of the elephants is very great, and it should be remembered that the estimate for the last year's expenditure was made without the knowledge that it would be necessary to meet so heavy an item as the cost of erecting a special building and providing keepers and provisions for these two animals.

As a colony of prairie dogs had been for some time a feature of the collection, it became necessary to provide suitable accommodations for them. Although a broad open meadow would best resemble their natural habitat it was thought best to place them in a little thicket of trees to the west of the main drive. Here there was built an inclosing wall 3½ feet high, and from the footing of this, galvanized iron mesh-work was placed in a trench 8 feet deep. This has been found sufficient to completely confine them. It is believed that this iron net will not corrode when buried so deeply in the ground. If this proves successful for a series of years it will be a great advantage, as it has usually been thought in Zoological Gardens necessary to excavate completely the inclosures for burrowing animals and to cement the bottom. This is very expensive, and the result is that but few colonies of burrowing animals are seen. It is hoped to add several colonies of this nature, including some of the most characteristic American rodents.

A list of the accessions to the park during the year is given herewith. (Exhibit A.) Many of them could not be accommodated in the houses already erected and have been assigned to quarters more or less temporary or to small cages scattered along the main road. Many more animals could have been procured had it been possible to suitably accommodate them. The most important accession is the Asiatic elephant "Dunk," which was presented to the park on April 30, 1891, by Mr. James E. Cooper, the proprietor of the Adam Forepaugh shows. The elephant is a fine animal, about 25 years of age, very docile and tractable, and a very valuable addition to the collection. Mr. Cooper not only gave this elephant, but in order to insure success in keeping him loaned another, "Golddust," to serves a a companion, it being well known that solitary elephants suffer greatly from loneliness.

When commissioners were sent to South America to collect material for the World's Columbian Exposition of 1893 it was thoughtfully suggested by Mr. W. E. Curtis, chief of the Latin-American Bureau of the State Department, that they might be also willing to collect animals for the park. Authority was therefore given them to incur expenditures not to exceed $300 for each person, and several accessions have been made by this means. The experiment has not, however, proved as satisfactory as could be wished, as the animals sent are usually badly cared for on shipboard.

Several animals have been born in the park during the year, the most noteworthy being a young female bison. It is believed that these animals will breed freely in confinement and that by this means the species may be kept indefinitely perpetuated,

The mortality during the year has been considerable. A great proportion of the animals that have died have succumbed immediately after arrival, either being in bad condition from injury or otherwise, when shipped, or being too delicate to stand transportation. Those who send specimens to the park should always take care to keep the animals in confinement for some time before shipping and should ask for directions as to the proper method of boxing. Many animals are killed by being sent in an improper manner and by being either starved or provided with improper food. The animals received from South America have been very frequently moribund when received. This is partly due to the customs regulations at New York City, which cause considerable delay in the reshipment of animals to this city.

The beautiful specimen of the big horn sheep (*Ovis montana*) succumbed to an attack of apoplexy, while the animals were still confined in the contracted yards in the rear of the Smithsonian Institution. A post-mortem examination showed the animal to be in an excellent physical condition, and it is believed that lack of exercise was the principal cause of the disorder that terminated its existence. As far as can be judged from this case there appears to be no reason whatever why this sheep, so rare in zoological collections, should not thrive in captivity if a suitable range of rocks and cliffs such as is found in the National Zoological Park is given to it.

The close of the year finds the work of the park progressing steadily and as rapidly as the funds appropriated by Congress will admit. The interest of the public is found to be very great, much more in fact than had been anticipated. There can be no doubt that in the course of a few years the park will become one of the chief attractions of a city already famous for its sights, offering as it does a combination entirely unique, exquisitely beautiful natural scenery with the charming aspects of varied animal life.

It has already been noticed that the one roadway is too narrow for the accommodaion of the large number of carriages that frequent the park on Sundays, the throngs between the hours of 3 and 5 p. m. being so great as to endanger visitors, and it it earnestly desired to extend the system of roads in accordance with a plan already laid out. The bridge, from necessary economy, was restricted to a width just sufficient to allow carriages to pass, no footway being provided. In view of the throng already referred to, this offers another source of danger, and it is contemplated building footways on projecting brackets along either side of the bridge should funds be appropriated for the purpose. Either this or a bridge for foot passengers alone will be absolutely essential.

EXHIBIT A.

*List of accessions.*

| Name. | Specimens. |
|---|---|
| Black-faced Coaita (*Ateles ater*) | 2 |
| Puma (*Felis concolor*) | 1 |
| Ocelot (*Felis pardalis*) | 2 |
| Wildcat (*Lynx rufus*) | 1 |
| Black Wolf (*Canis occidentalis var.*) | 1 |
| Coyote: Prairie Wolf (*Canis latrans*) | 3 |
| Red Fox (*Vulpes fulvus*) | 4 |
| Mink (*Putorius vison*) | 1 |
| Black-footed Ferret (*Putorius nigripes*) | 8 |
| Bridled Weasel (*Putorius frenatus*) | 1 |
| Cacomistle: American Civet Cat (*Bassaris astuta*) | 3 |
| American Badger (*Taxidea americana*) | 6 |
| Raccoon (*Procyon lotor*) | 2 |
| Harbor Seal (*Phoca vitulina*) | 1 |
| Asiatic Elephant (*Elephas indicus*) | 2 |
| Peccary (*Dicotyles tajaçu*) | 6 |
| Virginia Deer (*Cariacus virginianus*) | 3 |
| South American Red Deer (*Coassus rufus*) | 1 |
| European Hedgehog (*Erinaceus europæus*) | 8 |
| Red Squirrel (*Sciurus hudsonius*) | 1 |
| Gray Squirrel (*Sciurus carolinensis*) | 1 |
| Flying Squirrel (*Sciuropterus volucella*) | 1 |
| Chipmunk (*Tamias striatus*) | 3 |
| Prairie Dog (*Cynomys ludovicianus*) | 74 |
| Woodchuck (*Arctomys monax*) | 4 |
| Muskrat (*Fiber zibethicus*) | 4 |
| Beaver (*Castor fiber*) | 1 |
| Canada Porcupine (*Erethizon dorsatus*) | 2 |
| Crested Porcupine (*Hystrix cristata*) | 3 |
| English Rabbit (*Lepus cuniculus*) | 3 |
| White Rabbit (*Lepus cuniculus*) | 2 |
| Angora Rabbit (*Lepus cuniculus*) | 2 |
| Gray Rabbit (*Lepus sylvaticus*) | 4 |
| White-tailed Jack Rabbit (*Lepus campestris*) | 2 |
| Black-tailed Jack-rabbit (*Lepus callotis*) | 2 |
| Agouti (*Dasyprocta agouti*) | 1 |
| Guinea Pig (*Cavia aperea*) | 1 |
| Small Anteater (*Tamandua tetradactyla*) | 1 |
| Small Armadillo (*Tatusia novemcincta*) | 1 |
| Opossum (*Didelphys virginiana*) | 12 |
| Pied-billed Grebe (*Podilymbus podiceps*) | 1 |
| Night Heron (*Nycticorax nycticorax nævius*) | 2 |
| Cariama (*Cariama cristata*) | 1 |
| Woodcock (*Philohela minor*) | 1 |
| Quail: Bob White (*Colinus virginianus*) | 1 |
| Scaled Partridge (*Callipepla squamata*) | 2 |
| Leghorn Chicken (*Gallus bankiva*) | 1 |
| Pea Fowl (*Pavo cristata*) | 2 |
| Marsh Hawk (*Circus hudsonius*) | 3 |
| Red-shouldered Hawk (*Buteo lineatus*) | 5 |
| Bald Eagle (*Haliæetus leucocephalus*) | 1 |
| Sparrow Hawk (*Falco sparverius*) | 3 |
| Barn Owl (*Strix pratincola*) | 10 |
| Long-eared Owl (*Asio wilsonianus*) | 1 |
| Short-eared Owl (*Asio accipitrinus*) | 1 |
| Acadian Owl (*Nyctala acadica*) | 3 |
| Screech Owl (*Megascops asio*) | 7 |
| Great Horned Owl (*Bubo virginianus*) | 4 |
| Horned Lark (*Otocoris alpestris*) | 1 |
| Crow (*Corvus americanus*) | 1 |
| Alligator (*Alligator mississippiensis*) | 6 |
| Green Iguana (*Iguana Sp.?*) | 1 |
| Chuck-molly (*Sauromalus ater*) | 4 |
| Horned Toad (*Phrynosoma douglassi*) | 3 |
| Gila Monster (*Heloderma suspectum*) | 1 |
| Glass Snake (*Opheosaurus ventralis*) | 1 |
| Galapagos Tortoise (*Testudo ephippium*) | 1 |
| Ground Rattlesnake (*Caudisona miliaria*) | 1 |
| Water Moccasin (*Ancistrodon piscivorus*) | 1 |
| Copperhead (*Ancistrodon contortrix*) | 1 |
| Hog-nosed Adder (*Heterodon platyrhinus*) | 5 |
| Black Snake (*Bascanion constrictor*) | 1 |
| Bull Snake (*Pityophis sayi*) | 2 |
| Green Snake (*Cyclophis vernalis*) | 1 |
| King Snake (*Ophibolus getulus*) | 2 |
| Milk Snake (*Ophibolus doliatus*) | 2 |

Very respectfully,

FRANK BAKER,
*Acting Manager.*

MR. S. P. LANGLEY,
*Secretary Smithsonian Institution.*

## APPENDIX IV.

### REPORT OF THE LIBRARIAN FOR THE YEAR ENDING JUNE 30, 1891.

SIR: I have the honor respectfully to submit my report on the work of the library during the year from July 1, 1890, to June 30, 1891.

The work of recording and caring for the accessions has been carried on as during the preceding year, the entry numbers on the accession book running from 207,176 to 225,585.

The following condensed statement shows the character and number of these accessions:

*Publications received between July 1, 1890, and June 30, 1891.*

| | Octavo or smaller. | Quarto or larger. | Total. |
|---|---|---|---|
| Volumes | 1,844 | 837 | 2,681 |
| Parts of volumes | 9,439 | 11,086 | 20,525 |
| Pamphlets | 3,130 | 639 | 3,769 |
| Charts | | | 319 |
| Total | | | 27,294 |

Of these publications, 7,720 (namely, 424 volumes, 6,413 parts of volumes, and 883 pamphlets) were retained for use in the National Museum, and 754 medical dissertations were deposited in the library of the Surgeon-General, U. S. Army. The remainder were promptly sent to the Library of Congress on the Monday following their receipt.

In carrying out the Secretary's plan of increasing the library by exchanges, 1,327 letters asking for new exchanges, or calling attention to deficiencies in series already in the library, were written; and in response 475 new exchanges were acquired by the Institution, and 248 defective series were completed, either wholly or as far as the publishers were able to supply the missing parts. The value of this undertaking is well shown by the large increase of the actual accessions in comparison with those of the last fiscal year. In 1889–'90 the total number of accessions was 20,187; in 1890–'91 it was 27,294, showing a gain of 7,107 over 1889–'90.

The following publications have been added to the list of regular serials:

A. A. Bulletin.
Aarbog, Norske Geografiske Selskab.
Aarbog, Norske Geologiske Undersøgelse.
Aarsberetning, Danske Sløjdforening.
Abhandlungen des Botanischen Vereins der Provinz Brandenburg.
Abhandlungen zur Geographischen Specialkarte von Elsass-Lothringen.
Abhandlungen der Königlichen Meteorologischen Gesellschaft, Preussen.
Abhandlungen des Königlichen Preussischen Meteorologischen Instituts.
Academy, Boston.
Actes de la Société Sinico-Japonaise, Paris.
Adams' Magazine.
African.
Agricultural Gazette, Sydney, N. S. W.
Agricultural Record, Trinidad.
Album der Natuur.
Allgemeine Lutherische Kirchenzeitung.
Alpine Journal [Alpine Club, London].
American Apiculturist.
American Catholic Quarterly Review.
American Journal of Education.
Am Urquell.

Analostan Magazine.
Analyst.
Ancre de Saint-Dizier.
Annales Agronomiques.
Annales de l'École des Sciences Politiques.
Annales de la Société Agronomique, Nancy.
Annales de l'Observatoire de Nice.
Annales du Conservatoire de l'Art, Paris.
Annales de la Propagation de la Foi.
Annales des Sciences Géologiques.
Annali del Reale Istituto Tecnico, Udine.
Annals of the American Academy of Political and Social Science.
Année Scientifique et Industrielle.
Annuaire de l'Économie Politique.
Annuaire de la Société d'Émulation de la Vendée.
Annuaire de l'Association pour l'Encouragement des Études Grecques.
Annuaire Statistique de la Bohème.
Annuario della R. Università, Torino.
Annuario della Università di Modena.
Annual, Geologists' Association, London.
Annual Report of the Forestry Division, Department of Agriculture.
Annual Report of the Manchester Steam Users' Association.
Antiquary.
Anzeiger für Berg-, Hütten- und Maschinenwesen.
Arbeiten aus dem Zoologisch-Zootomischen Institut, Graz.
Archæologica Scotica.
Architecture, L', et la Construction dans le Nord, Lille.
Archiv für Christliche Kunst.
Archiv für Mathematik.
Archives Botaniques du Nord de la France.
Archives de Physiologie Normale et Pathologique.
Archivio de la Società Romana di Storia Patria.
Archivio di Litteratura Biblia ed Orientale.
Army and Navy Gazette.
Art (L') dans les Deux Mondes.
Artesano, El.
Atti della Accademia Pontaniana.
Atti del Museo Civico di Storia Naturale di Trieste.
Atti della Società Italiana di Scienze Naturali.
Atti e Memorie della Deputazione di Storia Patria, Bologna.
Aufzeichnungen des Architecten- und Ingenieur-Vereins für Niederrhein und Westphalen.
Aus Allen Welttheilen.
Australian Ironmonger.
Beiträge zur Kunde Ehst-, Liv-, und Kurlands.
Bergmannsfreund.
Berichte des Märkischen Forstvereins.
Berichte der Schweizerischen Botanischen Gesellschaft.
Berliner Missionsberichte.
Biblia.
Bibliographie de la Suisse.
Bibliothèque des Travaux Historiques et Archéologiques.
Boletin de la Comision del Mapa Geológico de España.
Boletin del Instituto Geografico Argentino.
Boletin del Instituto Libre de Enseñanza, Madrid.
Boletin del Observatorio Astronómico Nacional de Tacubaya.
Bollettino del Museo Patrio di Archeologia, Milano.
Bollettino della R. Accademia Medica di Genova.
Bollettino della Società di Naturalisti di Napoli.
Bollettino Statistico Mensile, Municipio di Milano.
Bollettino Officiale del Ministero del Tesoro, Roma.
Boston Budget.
Botaniste, Le.
Brassey's Naval Annual.
Brick Roadways.
Buffalo Christian Advocate.
Builder, London.
Building Register.
Bulletin of the Agricultural Experiment Station, Auburn, Ala.
Bulletin of the American Chemical Society.
Bulletin Annuel des Finances des Grandes Villes.
Bulletin de l'Association des Ingénieurs, Liège.
Bulletin du Comité de l'Afrique Française.
Bulletin de la Commission Archéologique et Littéraire de l'Arrondissement, Narbonne.
Bulletin de la Commission Départementale des Monuments Historiques, Arras.
Bulletin of the Department of Agriculture (of Queensland).
Bulletin of the North Carolina Experiment Station.
Bulletin of the Ontario Agricultural Experiment Station.
Bulletin de la Société Académique Indo-Chinoise.
Bulletin de la Société Archéologique de Touraine.
Bulletin de la Société Centrale d'Agriculture, Paris.
Bulletin de la Société Départementale d'Horticulture de la Seine.
Bulletin de la Société d'Émulation d'Abbeville.
Bulletin de la Société d'Encouragement pour l'Industrie Nationale, Paris.
Bulletin de la Société des Études Maritimes et Coloniales.
Bulletin de la Société d'Études des Sciences Naturelles, Reims.
Bulletin de la Société de Géographie de Lille.
Bulletin de la Société de Géographie de Toulouse.
Bulletin de la Société de Géographie Commerciale du Havre.

Bulletin de la Société Historique et Archéologique de l'Orne.
Bulletion de la Société de l'Industrie Minérale, Saint-Etienne.
Bulletin de la Société Languedocienne de Géographie.
Bulletin Mensuel de la Bibliothèque Nationale, Paris.
Bulletin Mensuel de la Société Linnéenne de Normandie.
Bulletin de la Société Mathématique, Paris.
Bulletin de la Société Neuchâteloise de Géographie.
Bulletin de la Société Royale de Botanique, Bruxelles.
Bulletin de la Société de Topographie, Paris.
Bulletin of the South Dakota Agricultural Experiment Station.
Bulletin of the State College, Pennsylvania.
Bulletion of the United States Board on Geographic Names.
Bulletin of Recent Changes in Aids to Navigation, U. S. Light-House Board.
Bulletin Mensuel de la Commission Météorologique du Calvados.
Bulletin Météorologique—Central Physical Observatory, St. Petersburg.
Bulletin Scientifique de la France et de la Belgique.
Bullettino della Società di Scienze Naturali ed Economiche, Palermo.
Caermarthenshire Notes and Queries.
Canadian Horticulturist.
Casopis pro pěstování mathematiky a fisiky, Prag.
Census Bulletin [Eleventh Census].
Chemiker-Kalender.
Chemisch-technischer Anzeiger.
Chemist and Druggist of Australasia.
China, Glass and Lamps.
Chinese Recorder.
Chinese Scientific Magazine.
Christian Union.
Chronicle of the London Missionary Society.
Churchman.
Church News.
Church Review.
Ciel et Terre.
Cobden Club Publications.
Colliery Guardian.
Colliery Engineer.
Colman's Rural World.
Colorado College Studies.
Communications et Procès-Verbaux de la Société Mathématique de Kharkow.
Comptes Rendus Mensuels de la Société de l'Industrie minérale.
Comptes Rendus des Séances de la Société Archéologique de Bordeaux.
Congregationalist.
Correo de Sotavento.
Costa Rica Ilustrada.
Crop Bulletin, Ithaca, N. Y.
Cultura, La.
Curio Informant.
'Cyclist.
Dania.
Delphian Record.
Deutsche Bauzeitung.
Deutsche Chemikerzeitung.
Deutsche Gerberzeitung.
Deutsche Heereszeitung.
Deutsche Zeitung für die Französische Jugend.
Dingler's Polytechnisches Journal.
Dnevnik Antropologitsheskago Otdjela Imperatorskago Obshtshestva Lubitelei Estestvoznanija, Antropologii i Etnografii.
Dnevnik Zoölogitsheskago Otdjelenija—of the same.
École, L'.
Économiste, L'.
Éducateur, L'.
Éducation, L'.
Educational Journal.
Educational Record.
Educational Times.
Électricien, L'.
Electrotechniker.
Ellettricità, L'.
Engineering.
Engineering Magazine.
Engineering and Mining Journal, New York.
Entomologiste Génévois.
Export.
Fancier and Farm Herald.
Far and Near.
Farben-Industrie.
Farm, Field, and Stockman.
Farm and Implement News.
Farm News.
Fauna.
Financial Reform.
Fish-trades Gazette.
Forstwirthschaftliches Centralblatt.
Fotograf.
France Aérienne.
Fur Trade Review.
Gaceta Médica Catalana.
Galilée, Le.
Gas World.
Gazette de Portugal.
Genealogist.
Geografiska Föreningens Tidskrift, Helsingfors.
Géographie, La.
Geographisches Jahrbuch.
Geologiska Föreningens Förhandlingar, Stockholm.
Giornale ed Atti della Società di Acclimatazione, Palermo.
Giornale della Società Asiatica Italiana.
Gloucestershire Notes and Queries.
Goldthwaites' Geographical Magazine.
Gornyi Zhurnal.
Great Salt Laker.
Guido del Maestro Elementare Italiano.
Hansa.
Hat Review.
Honduras Mining Journal.
Hook and Line.
Humming Bird.
Hyde Park [Mass.] Historical Record.

Illustrated Official Journal [English Patent Office].
Illustrated South.
Immeuble, L', et la Construction dans l' Est.
Imperial and Asiatic Quarterly.
Indian Engineering.
Industria, La.
Industria e Invenciones.
Industries.
Instructor Venezolano.
Iron.
Iron and Coal Trades Review.
Ironmonger.
Jaarboekje voor de Leden, Koninklijk Instituut van Ingenieurs.
Jahrbuchder Allgemeinen Geschichtsforschenden Gesellschaft, Berlin.
Jahrbuch der Königlich Preussischen Kunstsammlungen.
Jahrbuch der Preussischen Forst- und Jagdgesetze.
Jahrbuch des Schlesischen Forstvereins.
Jahrbuch des Schweizerischen Alpen-Club.
Jahrbuch des Ungarischen Karpathenvereins.
Jahresberichte der Akademie für Handel und Industrie, Graz.
Jahresberichte des Landwirthschaftlichen Vereins, Bonn.
Jahresberichte der Norddeutschen Seewarte.
Jahresberichte, Realschule zu Basel.
Jahresberichte des Stuttgarter Ärtzlichen Vereins.
Jahresberichte des Württembergischen Vereins für Handelsgeographie.
Jahresberichte über die Fortschritte auf dem Gebiete der Agricultur-Chemie.
Jewellers' Circular.
Jewish Messenger.
Journal of the American Social Science Association.
Journal of the Anthropological Society of Bombay.
Journal of the Bombay Natural History Society.
Journal of the British Astronomical Association.
Journal of the Manchester Geographical Society.
Journal of the Royal Asiatic Society (Straits Branch.)
Journal of the Statistical and Social Inquiry Society of Ireland.
Journal of the Tokyo Geographical Society.
Journal des Pflanzenphysiologischen Instituts der Königlichen Universität, Breslau.
Journal of Christian Philosophy.
Journal du Ciel.
Journal of Comparative Neurology.
Journal of Education (London).
Journal of Electro-Therapeutics.
Journal of Finance.
Lithograpic Art Journal.
Living Church Quarterly.
Livre, Le, d'Or du Salon.
Lloyd's Weekly Newspaper.
Lux.
Machinery and Iron, Steel Trades-Review.
Machinery Market.
Maestro Elementare Italiano.
Magisterio Español.
Magyar Mérnök-és Építész-Egylet Közlönyi.
Maine Historical and Genealogical Recorder.
Marine Engineer.
Mechanical Progress.
Mechanics.
Meddelande, Finska Forstföreningen.
Mediterranean Naturalist.
Mémoires de l'Académie des Sciences, Clermont-Ferrand.
Mémoires et Bulletin de la Société d'Archéologie de Touraine.
Mémoires de la Société des Sciences et Arts, Vitry-le-François.
Mémoires de la Société des Sciences Naturelles et Archéologiques, Gueret.
Memoirs and Proceedings of the Manchester Literary and Philosopical Society.
Memorias de la Comision del Mapa Geológico de España.
Memorial de Artilleria.
Meteorological Observations, Sydney, N. S. W.
Meteorologische Zeitschrift.
Michigan School Moderator.
Miller.
Mining News.
Mittheilungen des Deutschen Wissenschaftlichen Vereins in Mexico.
Mittheilungen des Physiologischen Laboratoriums, Stockholm.
Mittheilungen der Geographischen Gesellschaft, Lübeck.
Mittheilungen der Geologischen Landesanstalt, Strassburg.
Mittheilungen der Historischen Gesellschaft, Berlin.
Mittheilungen des Instituts für Oesterreichische Geschichtsforschung.
Mittheilungen des K. K. Technischen Gewerbe-Museums.
Mittheilungen der Ostschweizerischen Geographisch - commerciellen Gesellschaft.
Mittheilungen des Techniker-Vereins, New York.
Mittheilungen des Vereins für Geschichte der Stadt Meissen.
Mittheilungen aus dem Gesammten Gebiete der Englischen Sprache und Litteratur.
Mittheilungen aus dem Gebiete der Historisch-antiquarischen Forschungen.
Mittheilungen über Gegenstände des Artillerie - und Genie-Wesens.
Monist.
Moniteur des Produits Chimiques et de la Droguerie.
Moniteur Scientifique du Dr. Quesneville.

Monthly Review (Iowa Weather and Crop Service).
Musical Record.
Musical Times.
Nachrichten über Deutsche Alterthumsfunde.
National Geographic Magazine.
Narragansett Historical Register.
Naturalists' Gazette.
Nautical Magazine.
New England Magazine.
New Zealand Journal of Science.
New Zealand Schoolmaster.
Nieuwe Schoolblad.
Nordiske Fortidsminder.
Northwestern Architect.
Notes and Gleanings (Exeter, England).
Notulen, Koninklijk Instituut van Ingenieurs, The Hague.
Nunquam Otiosus.
Nyt Tidsskrift for Mathematik.
Obrero, El.
Observaciones verificadas—Observatory of Manila.
Occasional Papers of the California Academy of Science.
Oesterreichische Touristen-Zeitung.
Oölogist.
Papers of the American Historical Association.
Paper Record.
Periodico della Società Storica Comense.
Phonetic Journal.
Phonogram.
Photo-American Review.
Photographic News.
Photographisches Archiv.
Pottery Gazette.
Power.
Practical Engineer.
Practical Farmer.
Prähistorische Blätter.
Praktischer Maschinen-Constructeur.
Printing Times and Lithographer.
Proceedings of the Geologists' Association, London.
Proceedings of the Natural History Society, Tokyo.
Proceedings of the Rochester Academy of Science.
Proceedings of the South Staffordshire Institute of Iron and Steel Works Managers.
Proceedings and Transactions of the Liverpool Biological Society.
Prometheus.
Prosvestni Glasnik.
Publishers' Circular.
Quarterly Journal of Economics.
Quarterly Statement of the Palestine Exploration Fund.
Quellen zur Schweizerischen Geschichte.
Raccolta Storica della Società Storica Comense.
Railroad Gazette.
Railway Master Mechanic.
Report of the Canadian Patent Office.
Recueil des Travaux de la Société d'Agriculture, Sciences et Arts d'Agen.
Réforme Sociale, La.
Repertorium Annum Literaturae Botanicæ.
Report of the British and Foreign School Society.
Report of the Illinois State Historical Library.
Report of the Street Railway Association of the State of New York.
Report of the Ohio Society of Surveyors and Civil Engineers.
Report of Proceedings of the Manchester Steam Users' Association.
Répertoire des Travaux de la Société de Statistique de Marseilles.
Revista Argentina de Historia Natural.
Revista General de la Marina.
Revista de Geografia Comercial.
Revista Minera.
Revista de Obras Públicas e Minas.
Revista Tecnológico Industrial.
Revista Trimensal do Instituto Historico do Rio de Janeiro.
Revue Belge Militaire.
Revue du Cercle Militaire, Paris.
Revue Chrétienne.
Revue des Études Grecques.
Revue Géologique Suisse.
Revue Historique.
Revue Internationale de Bibliographie.
Revue Internationale de l'Électricité.
Revue Numismatique.
Revue Scientifique du Bourbonnais.
Revue Théologique.
Rivista Italiana di Scienze Naturali.
Rivista Marittima.
Rivista di Ostetricia e Ginecologia.
Russkij Natshalniy Utshetel.
Sanitary Journal.
Sanitary Record.
Schleswig-Holsteinsche Schulzeitung.
School Guardian.
School Journal.
Schoolmaster.
Schriften des Naturwissenschaftlichen Vereins des Harzes.
Schweizerisches Archiv für Thierheilkunde.
Schweizerische Zeitschrift für das Forstwesen.
Scottish Naturalist.
Semaine, La, des Constructeurs.
Sfinge, La.
Sitzungsberichte der Historischen Gesellschaft, Berlin.
Sitzungsberichte der Naturforschenden Gesellschaft, Leipzig.
Soobshtsheija Kharkofskago Matematitsheskago Obshtshestva.
Statesman's Yearbook.
Street Railway Journal.
Studi Senesi.
Sugar Cane.
Teacher.
Technisch-chemisches Jahrbuch.
Technische Mittheilungen für Malerei.
Theologisch Tijdschrift.
Theologisches Litteraturblatt.
Theologisk Tidsskrift.
Tidskrift for Folkundervisningen.
Tidsskrift for Physik og Chemi.

Transactions of the Astronomical and Physical Society of Toronto.
Transactions of the Maine State Pomological Society.
Transactions of the Mining Institute of Scotland.
Transactions of the Perthshire Society of Natural Science.
Treasury.
Utshenyja Zapiskii—Imperial University, Kazan.
Uhland's Technische Rundschau.
United Service.
Unsere Zeit.
Verbatim Report—American Street Railway Association.
Verdandi.
Verhandlungen des Deutschen Wissenschaftlichen Vereins zu Santiago.
Veröffentlichungen der Grossherzoglichen Sternwarte zu Karlsruhe.
Versammlungen des Architekten- und Ingenieurvereins für Niederrhein und Westphalen.
Vierteljahresschrift über die Fortschritte auf dem Gebiete der Chemie der Nahrungs- und Genussmittel.
Vierteljahresschrift für Volkswirthschaft, Politik und Kulturgeschichte.
Vital Record of Rhode Island.
Vjestnik Obshtshestvennoj Gigieny, Sudebnoj i Praktitsheskoj Meditsiny.
Vjestnik Sadovodstva, Plodovodstva i Ogorodnitshestva.
Volkskunde.
Vor Ungdom.
Watchmaker, Jeweler, and Silversmith.
Weather Crop Bulletin, Iowa.
Western Antiquary.
Wheelman's Gazette.
Wisconsin Journal of Education.
Wisconsin Naturalist.
Witterungsbeobachtungen—K. Forst-Akademie, Eberswalde.
Wood and Iron.
Wyoming State Journal.
Zapiski po Gidrografi.
Zee, De.
Zeitschrift des Bayerishen Kunst- und Gewerbe-Vereins.
Zeitschrift des Harz-Vereins für Geschichte und Alterthumskunde.
Zeitschrift des Münchener Alterthumsvereins.
Zeitschrift des Vereins für Volkskunde, Berlin.
Zeitschrift für Bauwesen.
Zeitschrift für Electrotechnik.
Zeitschrift für Forst- und Jagdwesen.
Zeitschrift für Forstwesen.
Zeitschrift für Instrumentenkunde.
Zeitschrift für Oesterreichische Gymnasien.
Zeitschrift für Spiritus-Industrie.
Zeitschrift für Vermessungswesen.
Zeitschrift für Xylographen.

The following universities have sent complete sets of all their academic publications, including the inaugural dissertations delivered by the students on graduation: Basel, Bern, Bonn, Breslau, Dorpat, Erlangen, Freiburg-in-Breisgau, Giessen, Göttingen, Greifswald, Halle-an-der-Saale, Heidelberg, Helsingfors, Jena, Kiel, Königsberg, Leipzig, Louvain, Lund (two sendings), Rostock, Strasburg, Tübingen, Utrecht, Vesterås, Würzburg, and Zurich.

Among other important accessions the following are worthy of notice: A large series of Italian Government publications from the Italian exchange bureau; Shurtleff's Topographical and Historical Description of Boston, and the "Memorial of John Boyle O'Reilly," from the Hon. Harlan P. Paige, Boston; Gore's "Electrolytic Separation of Metals," from the author; from the British Museum, Vol. 1, of the "Catalogue of the Cuneiform Tablets in the Kouyunjik Collection," "The Book of the Dead. Facsimile of the Papyrus of Ani," Vol. 9 of the "Catalogue of Oriental Coins," and "Catalogue of Greek Coins, Pontus, Paphlagonia," etc.; from the Natural History Division of the same museum, "Catalogue of Birds," Vols. 13, 15, and 18, "Catalogue of Fossil Cephalipoda," part 2, "Catalogue of Fossil Fishes," part 2, and "Catalogue of Fossil Reptilia and Amphibia," part 4; Vol. 10 of Nicholai von Kokscharow's "Materialien zur Mineralogie Russlands," from the author; a set of Ohio State publications, from the State Library at Columbus; the concluding volumes of Lilljeborg's "Sveriges och Norges Fiskar," from the author; four large quarto volumes from the Società Romana di Storia Patria, "Il Regesto Sublacense del Undecesimo Secolo," and "Il Regesto di Farfa;" Plana's "Théorie du Mouvement de la Lune," published in 1832, from the Royal Academy of Sciences, Turin; a large series of official publications of the different provinces, etc., of India, through the Office of the Secretary of State for India; a large series of French Government publications, through the Bureau Français des Echanges Internationaux; a full set of publications for the year, including all charts of the hydrographic offices of England, Italy, and Russia; Prof. van Beneden's recently published "Histoire Naturelle des Cétacés des

Mers d'Europe," from the author; municipal reports from the Stadt-Bibliothek, Hamburg; three important geological reports from the Norwegian Geological Survey, in addition to the Aarbog already mentioned; 103 more of the valuable dissertations delivered during the rectorship of Linnæus at Upsala, presented by the Högre Allmänna Läroverk at Vesterås, Sweden; Dr. Ferdinand Roemer's "Geologie von Oberbayern," in three volumes, from the Königlich Preussisches Oberbergamt, Breslau; "Introduction to the Study of Petrology: The Igneous Rocks," by Frederick H. Hatch, from the publishers, Messrs. Swan Sonneschein & Co., London; ten popular scientific treatises, from the Royal Hungarian Society of Natural History, Budapest; 23 pamphlets from the Society for Political Education, New York; 46 New Jersey State Reports, from the New Jersey Historical Society, Newark; from the Comision del Mapa Geologico, Madrid, the geological map of Spain, "Descripcion de la Provincia de Guadalajara," and "Estudies Geologicos de las Islas Balearicas," in addition to the memoirs and bulletins already mentioned; "Codex Diplomaticus Comitum Károlyi de Nagy-Károly," in four volumes, from Count Nagy-Károly, Budapest; the "Jeypore Portfolio of Architectural Details," a magnificent illustrated work, from His Highness the Maharajah of Jeypore; a large collection of valuable books from the National Library at Rio de Janeiro, including the magnificent folio "Flora Brasiliensis;" 39 scientific papers, relating largely to early Scandinavian and other early discoveries in America, from the Eugène Beauvois, Corbeson, France; the large folio "History of the Society of Writers to her Majesty's Signet," from the Society; a complete set of the publications of the Institut National de Géographie, Brussels; the "Recueil des Ordonnances," and "Recueil des Anciennes Coutumes," in 53 large quarto volumes, from the Belgian Exchange Commission; 6 pamphlets relating to Italian palethnology, from Inspector Pompeo Castelfranco, Milan; 20 pamphlets relating to human and comparative anatomy, from the author, Prof. H. Lebouco, of the University of Ghent; the Memorial edition of the "Scientific Papers of James Clerk Maxwell," from the Clerk Maxwell Memorial Committee, Cambridge.

Very respectfully submitted.

JOHN MURDOCH,
*Librarian.*

Mr. S. P. LANGLEY,
*Secretary of the Smithsonian Institution.*

## Appendix V.

### REPORT ON PUBLICATIONS OF THE YEAR ENDING JUNE 30, 1891.

#### SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

SIR: I have the honor to submit the following report upon the publications of the Smithsonian Institution for the year ending June 30, 1891:

Although no addition has been made during the year to the series of "Contributions to Knowledge," one issue has been made in a similar quarto form, consisting of a collection of botanical plates which had been prepared under the direction of the late Dr. Asa Gray between the years 1849 and 1859, now some forty years ago. This fragmentary series of 23 colored plates was designed as a portion of an extended illustrated work on "The Forest Trees of North America." In the Secretary's report to the Regents for 1849 it was stated:

"It is intended in this work to give figures from original drawings of the flowers, leaves, fruit, etc., of each principal species in the United States proper, for the most part of the size of nature, and so executed as to furnish colored or uncolored copies, the first being intended to give an adequate idea of the species, and the second for greater cheapness and more general diffusion. This work will be completed in three parts, in octavo, with an atlas of quarto plates, the first part to be published next spring. A portion of this will be occupied with an introductory dissertation giving the present state of our knowledge (divested as much as possible of all unnecessary technical terms), of the anatomy, morphology, and physiology of the tree, tracing its growth from the embryo to its full development and reproduction in the formation of fruit and seed. This will be illustrated by drawings from original dissections, under the microscope, and sketches made in every instance from nature."

The illustrations, so far as furnished, were skillfully drawn by Sprague, and were reproduced on stone by Sonrel, Prestele, and others; the impressions being carefully colored by hand. In consequence of various unforeseen hindrances and delays this interesting work, unfortunately, was never completed by its eminent projector; and no descriptive text was ever received from him, even of the plates which had been finished under his direction.

Notwithstanding the time which has elapsed since their original preparation and the comparatively limited range of their representation, it was thought advisable that they should be issued for the benefit of botanists, who will undoubtedly be interested in this unfinished work of their great leader and exponent, even without the advantage of his descriptive comments.

#### SMITHSONIAN MISCELLANEOUS COLLECTIONS.

The octavo publications of the year in this series are as follows:

No. 747. "An Account of the Progress in Astronomy, for the years 1887, 1888," by William C. Winlock. (From the Smithsonian Report for 1888.) Octavo pamphlet of 92 pages.

No. 748. "An Account of the Progress in Geology, for the years 1887, 1888," by W J McGee. (From the Smithsonian Report for 1888.) Octavo pamphlet of 44 pages.

No. 749. "An Account of the Progress in North American Paleontology, for the years 1887, 1888," by Henry S. Williams. (From the Smithsonian Report for 1888.) Octavo pamphlet of 66 pages.

No. 750. "An Account of the Progess in Petrography, for the years 1887, 1888," by George P. Merrill. (From the Smithsonian Report for 1888.) Octavo pamphlet of 28 pages.

No. 751. "An Account of Recent Progress in Dynamic Meteorology," by Cleveland Abbe. (From the Smithsonian Report for 1888.) Illustrated with 7 figures. Octavo pamphlet of 88 pages.

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Dyer; "Elementary Problems in Physiology," by J. S. Burdon-Sanderson; "The Life Work of Pasteur," by Sir Henry E. Roscoe; "On Heredity," by Sir William Turner. (From the Smithsonian Report for 1889.) Octavo pamphlet of 66 pages.

No. 779. "Papers on Physical Subjects," comprising "On Boscovich's Theory," by Sir William Thomson; "The Modern Theory of Light," by Oliver J. Lodge; "Photography in the Service of Astronomy," by R. Radau; "The Molecular Structure of Matter," by William Anderson. (From the Smithsonian Report for 1889.) Octavo pamphlet of 46 pages.

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No. 781. "Anthropological Papers," comprising "Anthropology in the last Twenty Years," by Rudolph Virchow; "Scandinavian Archæology," by Ingwald Unset; "The Last Steps in the Genealogy of Man," by Paul Topinard. (From the Smithsonian Report for 1889.) Octavo pamphlet of 62 pages.

No. 782. "An Account of the Progress in Anthropology for the year 1889," by Otis T. Mason. (From the Smithsonian Report for 1889.) Octavo pamphlet of 78 pages.

No. 783. "The State and Higher Education," by Herbert B. Adams. (From the Smithsonian Report for 1889.) Octavo pamphlet of 16 pages.

No. 784. "Geographical Latitude," by Walter B. Scaife. (From the Smithsonian Report for 1889.) Octavo pamphlet of 45 pages.

No. 785. "Bibliography of the Chemical Influence of Light," by Alfred Tuckerman. Octavo pamphlet of 25 pages.

"United States Board on Geographic Names." Bulletin No. 1. Issued December, 31, 1890. Octavo pamphlet of viii + 24.

SMITHSONIAN ANNUAL REPORTS.

No. 767. "Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution to July, 1888." This volume contains the Journal of Proceedings of the Board of Regents at the annual meeting held January 11, 1888; the Report of the Executive Committee of the Board, and the Report of the Secretary of the Institution, followed by the "General Appendix," in which are given: I. Record of progress in various branches of science for the years 1887 and 1888—in Astronomy, by William C. Winlock; in Geology, by W J McGee; in North American Paleontology, by Henry S. Williams; in Petrography, by George P, Merrill; in Meteorology, by Cleveland Abbe; in Chemistry, by F. W. Clarke; in Mineralogy, by Edward S. Dana; in Botany, by F. H. Knowlton, and in Anthropology, by Otis T. Mason. II. Miscellaneous papers—"Chronology of the Human Period," by J. Woodbridge Davis; "Were the Osages Mound-builders?" by J. F. Snyder; "The Progress of Science as exemplified in the Art of Weighing and Measuring," by William Harkness; "Determination of the Mean Density of the Earth by means of a Pendulum Principle," by J. Wilsing; "Amerriques Amerigho Vespucci and America," by Jules Marcou; "Progress of Oriental Science in America During 1888," by Cyrus Adler. III. Biographical Memoirs—a collection of memoirs of Spencer F. Baird and of Asa Gray; the whole forming an octavo volume of xli + 839 pages, illustrated with 9 figures and 1 map.

No. 768. "Annual Report of the Board of Regents of the Smithsonian Institution," showing the operations and condition of the U. S. National Museum for the year ending June 30, 1888. This report comprises, (I) Report of the Assistant Secretary of the Smithsonian Institution, G. Brown Goode, in charge of the National Museum, upon the Condition and Progress of the Museum; (II) Reports of the Curators of the Museum upon the Progress of Work During the year; (III) Papers Describing and Illustrating the Collections in the Museum; (IV) Bibliography of Publications and Papers Relating to the Museum during the year; (V) List of Accessions to the Museum

during the year. This report forms an octavo volume of xxii + 876 pages, illustrated with 159 figures, 109 plates, and 2 folding maps.

No. 746. "Proceedings of the Regents and Report of the Executive Committee for the year 1887–'88, together with acts of Congress for the year." (From the Smithsonian Report for 1888.) Octavo pamphlet of 33 pages.

No. 769. "Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution to July, 1889." This report includes the Journal of Proceedings of the Board of Regents of the Institution at the annual meeting held January 9, 1889; the Report of the Executive Committee of the Board; and the Report of the Secretary of the Institution; followed by the "General Appendix," which contains the following papers: The National Scientific Institutions at Berlin, by Albert Guttstadt; Hertz's Researches on Electrical Oscillations, by G. W. de Tunzelmann; Repetition of Hertz's Experiments, etc., by Frederick T. Trouton; Progress of Meteorology in 1889, by George W. Curtis; How Rain is Formed, by H. F. Blanford; On Aerial Locomotion, by F. H. Wenham; On the Movements of the Earth's Crust, by A. Blytt; Time-keeping in Greece and Rome, by F. A. Seely; Botanical Biology, by W. T. Thiselton Dyer; Elementary Problems in Physiology, by J. S. Burdon Sanderson; On Boscovich's Theory, by Sir Wililam Thompson; The Modern Theory of Light, by Oliver J. Lodge; Michelson's Recent Researches on Light, by Joseph Lovering; Photography in the Service of Astronomy, by R. Radau; The Lifework of a Chemist, by Sir Henry E. Roscoe; Memoir of Heinrich Leberecht Fleischer, by A Müller; Memoir of Gustav Robert Kirchhoff, by Robertson Helmholtz; On Heredity, by Sir William Turner; Anthropology in the Last Twenty Years, by Rudolph Virchow; Scandinavian Archæology, by Ingwald Unset; Progress of Anthropology in 1889, by Otis T. Mason; The Last Steps in the Genealogy of Man, by Paul Topinard; The State and Higher Education, by Herbert Adams; The Molecular Structure of Matter, by William Anderson; Aluminium, by H. C. Hovey; Alloys of Aluminium, by J. H. Dagger; The Eiffel Tower, by G. Eiffel and by William A. Eddy; The Great Terrestrial Globe at the Paris Exhibition of 1889; Geographical Latitude, by Walter B. Scaife; the whole forming an octavo volume of xlvi + 815 pages, illustrated with 33 figures.

No. 771. "Report of S. P. Langley, Secretary of the Smithsonian Institution, for the year ending June 30, 1890." Octavo pamphlet of 82 pages, illustrated with two maps.

No. 772. "Proceedings of the Regents, and Report of the Executive Committee for the year 1888–'89, together with acts of Congress for the year." (From the Smithsonian Report for 1889.) Octavo pamphlet of 36 pages.

Very respectfully yours,

W. B. TAYLOR,
*Editor.*

Mr. S. P. LANGLEY,
*Secretary Smithsonian Institution.*

GENERAL APPENDIX

TO THE

# SMITHSONIAN REPORT FOR 1891.

# ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; occasional reports of the investigations made by collaborators of the Institution; memoirs of a general character or on special topics, whether original and prepared expressly for the purpose, or selected from foreign journals and proceedings; and briefly to present (as fully as space will permit) such papers not published in the Smithsonian Contributions or in the Miscellaneous Collections as may be supposed to be of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution, from a very early date, to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, the Secretary, induced in part by the discontinuance of an annual summary of progress which for thirty years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoölogy, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889, a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report, for 1891.

# CELESTIAL SPECTROSCOPY.*

By William Huggins, F. R. S.

In 1866, I had the honor of bringing before this Association, at one of the evening lectures, an account of the first fruits of the novel and unexpected advances in our knowledge of the celestial bodies which followed rapidly upon Kirchhoff's original work on the solar spectrum and the interpretation of its lines.

Since that time a great harvest has been gathered in the same field by many reapers. Spectroscopic astronomy has become a distinct and acknowledged branch of the science, possessing a large literature of its own, and observatories specially devoted to it. The more recent discovery of the gelatine dry plate has given a further great impetus to this modern side of astronomy and has opened a pathway into the unknown of which even an enthusiast thirty years ago would scarcely have dared to dream.

In no science, perhaps, does the sober statement of the results which have been achieved appeal so strongly to the imagination and make so evident the almost boundless powers of the mind of man. By means of its light alone to analyze the chemical nature of a far-distant body; to be able to reason about its present state in relation to the past and future; to measure within an English mile or less per second the otherwise invisible motion which it may have towards or from us; to do more, to make even that which is darkness to our eyes light, and from vibrations which our organs of sight are powerless to perceive to evolve a revelation in which we see mirrored some of the stages through which the stars may pass in their slow evolutional progress—surely the record of such achievements, however poor the form of words in which they may be described, is worthy to be regarded as the scientific epic of the present century.

*Spectroscopic methods.*—I do not purpose to attempt a survey of the progress of spectroscopic astronomy from its birth at Heidelberg in 1859, but to point out what we do know at present, as distinguished from what

*Presidential address to the British Association for the Advancement of Science, at Cardiff, August, 1891. (*Report of Brit. Assoc.* 1891, vol. LXI, pp. 3-37.)

we do not know, of a few only of its more important problems, giving a prominent place, in accordance with the traditions of this chair, to the work of the last year or two.

In the spectroscope itself advances have been made by Lord Rayleigh by his discussion of the theory of the instrument and by Prof. Rowland in the construction of concave gratings.

Lord Rayleigh has shown that there is not the necessary connection, sometimes supposed, between dispersion and resolving power, as besides the prism or grating other details of construction and of adjustment of a spectroscope must be taken into account.

The resolving power of the prismatic spectroscope is proportional to the length of path in the dispersive medium. For the heavy flint glass used in Lord Rayleigh's experiments, the thickness necessary to resolve the sodium lines came out 1·02 centimeters. If this be taken as a unit, the resolving power of a prism of similar glass will be (in the neighborhood of the sodium lines) equal to the number of centimeters of its thickness. In other parts of the spectrum the resolving power will vary inversely as the third power of the wave length, so that it will be eight times as great in the violet as in the red. The resolving power of a spectroscope is therefore proportional to the total thickness of the dispersive material in use, irrespective of the number, the angles, or the setting of the separate prisms into which, for the sake of convenience, it may be distributed.

The resolving power of a grating depends upon the total number of lines on its surface and the order of spectrum in use, about 1,000 lines being necessary to resolve the sodium lines in the first spectrum.

As it is often of importance in the record of observations to state the efficiency of the spectroscope with which they were made, Prof. Schuster has proposed the use of a unit of purity as well as of resolving power, for the full resolving power of a spectroscope is realized in practice only when a sufficiently narrow slit is used. The unit of purity also is to stand for the separation of two lines differing by one-thousandth of their own wave length, about the separation of the sodium pair at D.

A further limitation may come in from the physiological fact that, as Lord Rayleigh has pointed out, the eye, when its full aperture is used, is not a perfect instrument. If we wish to realize the full resolving power of a spectroscope, therefore, the emergent beam must not be larger than about one-third of the opening of the pupil.

Up to the present time the standard of reference for nearly all spectroscopic work continues to be Ångström's map of the solar spectrum and his scale based upon his original determinations of absolute wave length. It is well known, as was pointed out by Thalén in his work on the spectrum of iron, in 1884, that Ångström's figures are slightly too small, in consequence of an error existing in a standard meter used by him. The corrections for this have been introduced into the tables of the wave lengths of terrestrial spectra collected and revised by a

committee of this Association from 1885 to 1887. Last year the committee added a table of corrections to Rowland's scale.

The inconvenience caused by a change of standard scale is, for a time at least, considerable; but there is little doubt that in the near future Rowland's photographic map of the solar spectrum and his scale based on the determinations of absolute wave length by Pierce and Bell, or the Potsdam scale, based on original determinations by Müller and Kempf, which differs very slightly from it, will come to be exclusively adopted.

The great accuracy of Rowland's photographic map is due chiefly to the introduction by him of concave gratings and of a method for their use by which the problem of the determination of relative wave lengths is simplified to measures of coincidences of the lines in different spectra by a micrometer.

The concave grating and its peculiar mounting, in which no lenses or telescope are needed, and in which all the spectra are in focus together, formed a new departure of great importance in the measurement of spectral lines. The valuable method of photographic sensitizers for different parts of the spectrum has enabled Prof. Rowland to include in his map the whole visible solar spectrum, as well as the ultra-violet portion as far as it can get through our atmosphere. Some recent photographs of the solar spectrum, which include A, by Mr. George Higgs, are of great technical beauty.

During the past year the results of three independent researches have appeared, in which the special object of the observers has been to distinguish the lines which are due to our atmosphere from those which are truly solar—the maps of M. Thollon, which, owing to his lamented death just before their final completion, have assumed the character of a memorial of him; maps by Dr. Becker; and sets of photographs of a high and a low sun by Mr. McClean.

At the meeting of this association in Bath, M. Janssen gave an account of his own researches on the terrestrial lines of the solar spectrum which owe their origin to the oxygen of our atmosphere. He discovered the remarkable fact that, while one class of bands varies as the density of the gas, other diffuse bands vary as the square of the density. These observations are in accordance with the work of Egoroff and of Olszewski, and of Liveing and Dewar on condensed oxygen. In some recent experiments Olszewski, with a layer of liquid oxygen 30 millimeters thick, saw, as well as four other bands, the band coincident with Fraunhofer's A; a remarkable instance of the persistence of absorption through a great range of temperature. The light which passed through the liquid oxygen had a light blue color resembling that of the sky.

Of not less interest are the experiments of Knut Ångström, which show that the carbonic acid and aqueous vapour of the atmosphere reveal their presence by dark bands in the invisible infra-red region, at the positions of bands of emission of these substances.

*Spectroscopic conditions.*—It is now some thirty years since the spectroscope gave us for the first time certain knowledge of the nature of the heavenly bodies, and revealed the fundamental fact that terrestrial matter is not peculiar to the solar system, but is common to all the stars which are visible to us.

In the case of a star such as Capella, which has a spectrum almost identical with that of the sun, we feel justified in concluding that the matter of which it is built up is similar, and that its temperature is also high, and not very different from the solar temperature. The task of analyzing the stars and nebulæ becomes however one of very great difficulty when we have to do with spectra differing from the solar type. We are thrown back upon the laboratory for the information necessary to enable us to interpret the indications of the spectroscope as to the chemical nature, the density and pressure, and the temperature of the celestial masses.

What the spectroscope immediately reveals to us are the waves which were set up in the æther filling all inter-stellar space, years or hundreds of years ago, by the motions of the molecules of the celestial substances. As a rule, it is only when a body is gaseous and sufficiently hot that the motions within its molecules can produce bright lines and a corresponding absorption. The spectra of the heavenly bodies are indeed, to a great extent absorption spectra, but we have usually to study them through the corresponding emission spectra of bodies brought into the gaseous form and rendered luminous by means of flames or of electric discharges. In both cases, unfortunately, as has been shown recently by Profs. Liveing and Dewar, Wüllner, E. Wiedemann and others, there appears to be no certain direct relation between the luminous radiation as shown in the spectroscope and the temperature of the flame, or of the gaseous contents of the vacuum tube—that is, in the usual sense of the term as applied to the mean motion of all the molecules. In both cases, the vibratory motions within the molecules to which their luminosity is due are almost always much greater than would be produced by encounters of molecules having motions of translation no greater than the average motions which characterize the temperature of the gases as a whole. The temperature of a vacuum tube through which an electric discharge is taking place may be low, as shown by a thermometer, quite apart from the consideration of the extreme smallness of the mass of gas, but the vibrations of the luminous molecules must be violent in whatever way we suppose them to be set up by the discharge; if we take Schuster's view that comparatively few molecules are carrying the discharge, and that it is to the fierce encounters of these alone that the luminosity is due, then if all the molecules had similar motions, the temperature of the gas would be very high.

So in flames where chemical changes are in progress, the vibratory motions of the molecules which are luminous may be, in connection with

the energy set free in these changes, very different from those corresponding to the mean temperature of the flame.

Under the ordinary conditions of terrestrial experiments, therefore, the temperature or the mean *vis viva* of the molecules may have no direct relation to the total radiation, which, on the other hand, is the sum of the radiation due to each luminous molecule.

These phenomena have recently been discussed by Ebert from the standpoint of the electro-magnetic theory of light.

Very great caution is therefore called for when we attempt to reason by the aid of laboratory experiments to the temperature of the heavenly bodies from their radiation, especially on the reasonable assumption that in them the luminosity is not ordinarily associated with chemical changes or with electrical discharges; but is due to a simple glowing from the ultimate conversion of the gravitational energy of shrinkage into molecular motion.

In a recent paper Stas maintains that electric spectra are to be regarded as distinct from flame spectra; and from researches of his own, that the pairs of lines of the sodium spectrum other than D are produced only by disruptive electric discharges. As these pairs of lines are found reversed in the solar spectrum, he concludes that the sun's radiation is due mainly to electric discharges. But Wolf and Diacon, and later, Watts, observed the other pairs of lines of the sodium spectrum when the vapor was raised above the ordinary temperature of the Bunsen flame. Recently, Liveing and Dewar saw easily, besides D, the citron and green pairs, and sometimes the blue pair and the orange pair, when hydrogen charged with sodium vapor was burning at different pressures in oxygen. In the case of sodium vapor, therefore, and presumably in all other vapors and gases, it is a matter of indifference whether the necessary vibratory motion of the molecules is produced by electric discharges or by flames. The presence of lines in the solar spectrum which we can only produce electrically, is an indication, however, as Stas points out, of the high temperature of the sun.

We must not forget that the light from the heavenly bodies may consist of the combined radiations of different layers of gas at different temperatures, and possibly be further complicated to an unknown extent by the absorption of cooler portions of gas outside.

Not less caution is needed if we endeavor to argue from the broadening of lines and the coming in of a continuous spectrum as to the relative pressure of the gas in the celestial atmospheres. On the one hand, it can not be gainsaid that in the laboratory the widening of the lines in a Plücker's tube follows upon increasing the density of the residue of hydrogen in the tube, when the vibrations are more frequently disturbed by fresh encounters, and that a broadening of the sodium lines in a flame at ordinary pressure is produced by an increase of the quantity of sodium in the flame; but it is doubtful if pressure, as distinguished from quantity, does produce an increase of the breadth of the

lines. An individual molecule of sodium will be sensibly in the same condition, considering the relatively enormous number of the molecules of the other gases, whether the flame is scantily or copiously fed with the sodium salt. With a small quantity of sodium vapor the intensity will be feeble except near the maximum of the lines; when, however, the quantity is increased, the comparative transparency on the sides of the maximum will allow the light from the additional molecules met with in the path of the visual ray to strengthen the radiation of the molecules farther back, and so increase the breadth of the lines.

In a gaseous mixture it is found, as a rule, that at the same pressure or temperature, as the encounters with similar molecules become fewer, the spectral lines will be affected as if the body were observed under conditions of reduced quantity or temperature.

In their recent investigation of the spectroscopic behavior of flames under various pressures up to forty atmospheres, Profs. Living and Dewar have come to the conclusion that though the prominent feature of the light emitted by flames at high pressure appears to be a strong continuous spectrum, there is not the slightest indication that this continuous spectrum is produced by the broadening of the lines of the same gases at low pressure. On the contrary, photometric observations of the brightness of the continuous spectrum, as the pressure is varied, show that it is mainly produced by the mutual action of the molecules of a gas. Experiments on the sodium spectrum were carried up to a pressure of forty atmospheres without producing any definite effect on the width of the lines which could be ascribed to the pressure. In a similar way the lines of the spectrum of water showed no signs of expansion up to twelve atmospheres; though more intense than at ordinary pressure, they remained narrow and clearly defined.

It follows therefore that a continuous spectrum can not be considered, when taken alone, as a sure indication of matter in the liquid or the solid state. Not only, as in the experiments already mentioned, such a spectrum may be due to gas when under pressure, but, as Maxwell pointed out, if the thickness of a medium, such as sodium vapor, which radiates and absorbs different kinds of light, be very great, and the temperature high, the light emitted will be of exactly the same composition as that emitted by lamp-black at the same temperature, for the radiations which are feebly emitted will be also feebly absorbed and can reach the surface from immense depths. Schuster has shown that oxygen, even in a partially exhausted tube, can give a continuous spectrum when excited by a feeble electric discharge.

Compound bodies are usually distinguished by a banded spectrum; but, on the other hand, such a spectrum does not necessarily show the presence of compounds—that is, of molecules containing different kinds of atoms—but simply of a more complex molecule, which may be made up of similar atoms, and be, therefore, an allotropic condition of the same body. In some cases—for example, in the diffuse bands of the

absorption spectrum of oxygen—the bands may have an intensity proportional to the square of the density of the gas, and may be due either to the formation of more complex molecules of the gas with increase of pressure or, it may be, to the constraint to which the molecules are subject during their encounter with one another.

It may be thought that at least in the coincidences of bright lines we are on the solid ground of certainty, since the length of the waves set up in the æther by a molecule, say of hydrogen, is the most fixed and absolutely permanent quantity in nature, and is so of physical necessity, for with any alteration the molecule would cease to be hydrogen.

Such would be the case if the coincidence were certain; but an absolute coincidence can be only a matter of greater or less probability, depending on the resolving power employed, on the number of the lines which correspond, and on their characters. When the coincidences are very numerous, as in the case of iron and the solar spectrum, or the lines are characteristically grouped, as in the case of hydrogen and the solar spectrum, we may regard the coincidence as certain; but the progress of science has been greatly retarded by resting important conclusions upon the apparent coincidence of single lines in spectroscopes of very small resolving power. In such cases, unless other reasons supporting the coincidence are present, the probability of a real coincidence is almost too small to be of any importance, especially in the case of a heavenly body which may have a motion of approach or of recession of unknown amount.

But even here we are met by the confusion introduced by multiple spectra, corresponding to different molecular groupings of the same substance and, further, to the influence of substances in vapor upon each other; for when several gases are present together the phenomena of radiation and reversal by absorption are by no means the same as if the gases were free from each other's influence, and especially is this the case when they are illuminated by an electric discharge.

I have said as much as time will permit and I think indeed sufficient to show that it is only by the laborious and slow process of most cautious observation that the foundations of the science of celestial physics can be surely laid. We are at present in a time of transition, when the earlier and, in the nature of things, less precise observations are giving place to work of an order of accuracy much greater than was formerly considered attainable with objects of such small brightness as the stars.

The accuracy of the earlier determinations of the spectra of the terrestrial elements is in most cases insufficient for modern work on the stars as well as on the sun. It falls much below the scale adopted in Rowland's map of the sun, as well as below the degree of accuracy attained at Potsdam by photography in a part of the spectrum for the brighter stars. Increase of resolving power very frequently breaks up into groups, in the spectra of the sun and stars, the lines which had

been regarded as single, and their supposed coincidence with terrestrial lines falls to the ground. For this reason many of the early conclusions based on observation as good as it was possible to make at the time with the less powerful spectroscopes then in use, may not be found to be maintained under the much greater resolving power of modern instruments.

*Spectroscopic Problems.*—The spectroscope has failed as yet to interpret for us the remarkable spectrum of the aurora borealis. Undoubtedly in this phenomenon portions of our atmosphere are lighted up by electric discharges; we should expect, therefore, to recognize the spectra of the gases known to be present in it. As yet we have not been able to obtain similar spectra from these gases artificially, and especially we do not know the origin of the principal line in the green, which often appears alone, and may have, therefore, an origin independent of that of the other lines. Recently the suggestion has been made that the aurora is a phenomenon produced by the dust of meteors and falling stars, and that near positions of certain auroral lines or flutings of manganese, lead, barium, thallium, iron, etc., are sufficient to justify us in regarding meteoric dust in the atmosphere as the origin of the auroral spectrum. Liveing and Dewar have made a conclusive research on this point, by availing themselves of the dust of excessive minuteness thrown off from the surface of the electrodes of various metals and meteorites by a disruptive discharge, and carried forward into the tube of observation by a more or less rapid current of air or other gas. These experiments prove that metallic dust, however fine, suspended in a gas will not act like gaseous matter in becoming luminous with its characteristic spectrum in an electric discharge similar to that of the aurora. Prof. Schuster has suggested that the principal line may be due to some very light gas which is present in too small a proportion to be detected by chemical analysis or even by the spectroscope in the presence of the other gases near the earth, but which, at the height of the auroral discharges is in a sufficiently greater relative proportion to give a spectrum. Lemström, indeed, states that he saw this line in the silent discharge of a Holtz machine on a mountain in Lapland. The lines may not have been obtained in our laboratories from the atmospheric gases on account of the difficulty of re-producing in tubes with sufficient nearness the conditions under which the auroral discharges take place.

In the spectra of comets the spectroscope has shown the presence of carbon presumably in combination with hydrogen, and also sometimes with nitrogen; and in the case of comets approaching very near the sun, the lines of sodium, and other lines which have been supposed to belong to iron. Though the researches of Prof. H. A. Newton and of Prof. Schiaparelli leave no doubt of the close connection of comets with corresponding periodic meteor swarms, and therefore of the probable identity of cometary matter with that of meteorites, with which the spec-

troscopic evidence agrees, it would be perhaps unwise at present to attempt to define too precisely the exact condition of the matter which forms the nucleus of the comet. In any case the part of the light of the comet which is not reflected solar light can scarcely be attributed to a high temperature produced by the clashing of separate meteoric stones set up within the nucleus by the sun's disturbing force. We must look rather to disruptive electric discharges, produced probably by processes of evaporation due to increased solar heat, which would be amply sufficient to set free portions of the occluded gases into the vacuum of space. May it be that these discharges are assisted, and indeed possibly increased, by the recently-discovered action of the ultra-violet part of the sun's light? Lenard and Wolfe have shown that ultra-violet light can produce a discharge from a negatively electrified piece of metal, while Hallwachs and Righi have shown further that ultra-violet light can even charge positively an unelectrified piece of metal. Similar actions on cometary matter, unscreened as it is by an absorptive atmosphere, at least of any noticeable extent, may well be powerful when a comet approaches the sun, and help to explain an electrified condition of the evaporated matter which would possibly bring it under the sun's repulsive action. We shall have to return to this point in speaking of the solar corona.

A very great advance has been made in our knowledge of the constitution of the sun by the recent work at the Johns Hopkins University by means of photography and concave gratings, in comparing the solar spectrum, under great resolving power, directly with the spectra of the terrestrial elements. Prof. Rowland has shown that the lines of thirty-six terrestrial elements at least are certainly present in the solar spectrum, while eight others are doubtful. Fifteen elements, including nitrogen, as it shows itself under an electric discharge in a vacuum tube, have not been found in the solar spectrum. Some ten other elements, inclusive of oxygen, have not yet been compared with the sun's spectrum.

Rowland remarks that of the fifteen elements named as not found in the sun, many are so classed because they have few strong lines, or none at all, in the limit of the solar spectrum as compared by him with the arc. Boron has only two strong lines. The lines of bismuth are compound and too diffuse. Therefore even in the case of these fifteen elements there is little evidence that they are really absent from the sun.

It follows that if the whole earth were heated to the temperature of the sun, its spectrum would resemble very closely the solar spectrum.

Rowland has not found any lines common to several elements, and in the case of some accidental coincidences, more accurate investigation reveals some slight difference of wave-length or a common impurity. Further, the relative strength of the lines in the solar spectrum is generally, with a few exceptions, the same as that in the elec-

tric arc, so that Rowland considers that his experiments show "very little evidence" of the breaking up of the terrestrial elements in the sun.

Stas in a recent paper gives the final results of eleven years of research on the chemical elements in a state of purity, and on the possibility of decomposing them by the physical and chemical forces at our disposal. His experiments on calcium, strontium, lithium, magnesium, silver, sodium, and thallium, show that these substances retain their individuality under all conditions, and are unalterable by any forces that we can bring to bear upon them.

Prof. Rowland looks to the solar lines which are unaccounted for as a means of enabling him to discover such new terrestrial elements as still lurk in rare minerals and earths, by confronting their spectra directly with that of the sun. He has already resolved yttrium spectroscopically into three components, and actually into two. The comparison of the results of this independent analytical method with the remarkable but different conclusions to which M. Lecoq de Boisbaudran and Mr. Crookes have been led respectively, from spectroscopic observation of these bodies when glowing under molecular bombardment in a vacuum tube, will be awaited with much interest. It is worthy of remark that, as our knowledge of the spectrum of hydrogen in its complete form came to us from the stars, it is now from the sun that chemistry is probably about to be enriched by the discovery of new elements.

In a discussion in the Bakerian Lecture for 1885, of what we knew up to that time of the sun's corona, I was led to the conclusion that the corona is essentially a phenomenon similar in the cause of its formation to the tails of comets—namely, that it consists for the most part probably of matter going from the sun under the action of a force, possibly electrical, which varies as the surface, and can therefore in the case of highly attenuated matter easily master the force of gravity even near the sun. Though many of the coronal particles may return to the sun, those which form the long rays or streamers do not return; they separate and soon become too diffused to be any longer visible, and may well go to furnish the matter of the zodiacal light, which otherwise has not received a satisfactory explanation. And further, if such a force exist at the sun, the changes of terrestrial magnetism may be due to direct electric action, as the earth moves through lines of inductive force.

These conclusions appear to be in accordance broadly with the lines along which thought has been directed by the results of subsequent eclipses. Prof. Schuster takes an essentially similar view, and suggests that there may be a direct electric connection between the sun and the planets. He asks further whether the sun may not act like a magnet in consequence of its revolution about its axis. Prof. Bigelow has recently treated the coronal forms by the theory of spherical harmonics, on the supposition that we see phenomena similar to those of free elec-

tricity, the rays being lines of force, and the coronal matter discharged from the sun, or at least arranged or controlled by these forces. At the extremities of the streams for some reasons the repulsive power may be lost, and gravitation set in, bringing the matter back to the sun. The matter which does leave the sun is persistently transported to the equatorial plane of the corona; in fact, the zodiacal light may be the accumulation at great distances from the sun along this equator of such like material. Photographs on a larger scale will be desirable for the full development of the conclusions which may follow from this study of the curved forms of the coronal structure. Prof. Schaeberle, however, considers that the coronal phenomena may be satisfactorily accounted for on the supposition that the corona is formed of streams of matter ejected mainly from the spot zones with great initial velocities, but smaller than 382 miles per second. Further, that the different types of the corona are due to the effects of perspective on the streams, from the earth's place at the time relatively to the plane of the solar equator.

Of the physical and the chemical nature of the coronal matter we know very little. Schuster concludes, from an examination of the eclipses of 1882, 1883, and 1886, that the continuous spectrum of the corona has the maximum of actinic intensity displaced considerably towards the red when compared with the spectrum of the sun, which shows that it can only be due in small part to solar light scattered by small particles. The lines of calcium and of hydrogen do not appear to form part of the normal spectrum of the corona. The green coronal line has no known representative in terrestrial substances, nor has Schuster been able to recognize any of our elements in the other lines of the corona.

*Stellar evolution.*—The spectra of the stars are almost infinitely diversified, yet they can be arranged with some exceptions in a series in which the adjacent spectra, especially in the photographic region, are scarcely distinguishable, passing from the bluish-white stars like Sirius, through stars more or less solar in character, to stars with banded spectra, which divide themselves into two apparently independent groups, according as the stronger edge of the bands is towards the red or the blue. In such an arrangement the sun's place is towards the middle of the series.

At present a difference of opinion exists as to the direction in the series in which evolution is proceeding, whether by further condensation white stars pass into the orange and red stages, or whether these more colored stars are younger and will become white by increasing age. The latter view was suggested by Johnstone Stoney in 1867.

About ten years ago Ritter in a series of papers discussed the behavior of gaseous masses during condensation, and the probable resulting constitution of the heavenly bodies. According to him, a star passes through the orange and red stages twice, first during a comparatively

short period of increasing temperature, which culminates in the white stage, and a second time during a more prolonged stage of gradual cooling. He suggested that the two groups of banded stars may correspond to these different periods, the young stars being those in which the stronger edge of the dark band is towards the blue, the other banded stars, which are relatively less luminous and few in number, being those which are approaching extinction through age.

Recently a similar evolutional order has been suggested, which is based upon the hypothesis that the nebulæ and stars consist of colliding meteoric stones in different stages of condensation.

More recently the view has been put forward that the diversified spectra of the stars do not represent the stages of an evolutional progress, but are due for the most part to differences of original constitution.

The few minutes which can be given to this part of the address are insufficient for a discussion of these different views. I purpose, therefore, to state briefly, and with reserve, as the subject is obscure, some of the considerations from the characters of their spectra which appeared to me to be in favor of the evolutional order in which I arranged the stars from their photographic spectra in 1879. This order is essentially the same as Vogel had previously proposed in his classification of the stars in 1874, in which the white stars, which are most numerous, represent the early adult and most persistent stage of stellar life; the solar condition that of full maturity and of commencing age; while in the orange and red stars with banded spectra we see the setting in and advance of old age. But this statement must be taken broadly, and not as asserting that all stars, however different in mass and possibly to some small extent in original constitution, exhibit one invariable succession of spectra.

In the spectra of the white stars the dark metallic lines are relatively inconspicuous, and occasionally absent, at the same time that the dark lines of hydrogen are usually strong, and more or less broad, upon a continuous spectrum, which is remarkable for its brilliancy at the blue end. In some of these stars the hydrogen and some other lines are bright, and sometimes variable.

As the greater or less prominence of the hydrogen lines, dark or bright, is characteristic of the white stars as a class, and diminishes gradually with the incoming and increase in strength of the other lines, we are probably justified in regarding it as due to some conditions which occur naturally during the progress of stellar life, and not to a peculiarity of original constitution.

To produce a strong absorption-spectrum a substance must be at the particular temperature at which it is notably absorptive; and further, this temperature must be sufficiently below that of the region behind from which the light comes for the gas to appear, so far as its special rays are concerned, as darkness upon it. Considering the high tem-

perature to which hydrogen must be raised before it can show its characteristic emission and absorption, we shall probably be right in attributing the relative feebleness or absence of the other lines, not to the paucity of the metallic vapors, but rather to their being so hot relatively to the substances behind them as to show feebly, if at all, by reversion. Such a state of things would more probably be found, it seems to me, in conditions anterior to the solar stage. A considerable cooling of the sun would probably give rise to banded spectra due to compounds, or to more complex molecules, which might form near the condensing points of the vapors.

The sun and stars are generally regarded as consisting of glowing vapors surrounded by a photosphere where condensation is taking place, the temperature of the photospheric layer from which the greater part of the radiation comes being constantly renewed from the hotter matter within.

At the surface the convection currents would be strong, producing a considerable commotion, by which the different gases would be mixed and not allowed to retain the inequality of proportions at different levels due to their vapor densities.

Now the conditions of the radiating photosphere and those of the gases above it, on which the character of the spectrum of a star depends, will be determined, not alone by temperature, but also by the force of gravity in these regions; this force will be fixed by the star's mass and its stage of condensation, and will become greater as the star continues to condense.

In the case of the sun the force of gravity has already become so great at the surface that the decrease of the density of the gases must be extremely rapid, passing in the space of a few miles from atmospheric pressure to a density infinitesimally small; consequently the temperature-gradient at the surface, if determined solely by expansion, must be extremely rapid. The gases here however are exposed to the fierce radiation of the sun, and unless wholly transparent would take up heat, especially if any solid or liquid particles were present from condensation or convection currents.

From these causes, within a very small extent of space at the surface of the sun, all bodies with which we are acquainted should fall to a condition in which the extremely tenuous gas could no longer give a visible spectrum. The insignificance of the angle subtended by this space as seen from the earth should cause the boundary of the solar atmosphere to appear defined. If the boundary which we see be that of the sun proper, the matter above it will have to be regarded as in an essentially dynamical condition—an assemblage, so to speak, of gaseous projectiles, for the most part falling back upon the sun after a greater or less range of flight. But in any case it is within a space of relatively small extent in the sun, and probably in the other solar stars, that the

reversion which is manifested by dark lines is to be regarded as taking place.

Passing backward in the star's life, we should find a gradual weakening of gravity at the surface, a reduction of the temperature-gradient so far as it was determined by expansion, and convection currents of less violence producing less interference with the proportional quantities of gases due to their vapor densities, while the effects of eruptions would be more extensive.

At last we might come to a state of things in which, if the star were hot enough, only hydrogen might be sufficiently cool relatively to the radiation behind to produce a strong absorption. The lower vapors would be protected, and might continue to be relatively too hot for their lines to appear very dark upon the continuous spectrum; besides, their lines might be possibly to some extent effaced by the coming in under such conditions in the vapors themselves of a continuous spectrum.

In such a star the light radiated towards the upper part ef the atmosphere may have come from portions lower down of the atmosphere itself, or at least from parts not greatly hotter. There may be no such great difference of temperature of the low and less low portions of the star's atmosphere as to make the darkening effect of absorption of the protected metallic vapors to prevail over the illuminating effect of their emission.

It is only by a vibratory motion corresponding to a very high temperature that the bright lines of the first spectrum of hydrogen can be brought out, and by the equivalence of absorbing and emitting power that the corresponding spectrum of absorption should be produced; yet for a strong absorption to show itself, the hydrogen must be cool relatively to the source of radiation behind it, whether this be condensed particles or gas. Such conditions, it seems to me, should occur in the earlier rather than in the more advanced stages of condensation.

The subject is obscure, and we may go wrong in our mode of conceiving of the probable progress of events, but there can be no doubt that in one remarkable instance the white-star spectrum is associated with an early stage of condensation.

Sirius is one of the most conspicuous examples of one type of this class of stars. Photometric observations combined with its ascertained parallax show that this star emits from forty to sixty times the light of our sun, even to the eye, which is insensible to ultra-violet light, in which Sirius is very rich, while we learn from the motion of its companion that its mass is not much more than double that of our sun. It follows that, unless we attribute to this star an improbably great emissive power, it must be of immense size, and in a much more diffuse and therefore an earlier condition than our sun; though probably at a later stage than those white stars in which the hydrogen lines are bright.

A direct determination of the relative temperature of the photospheres of the stars might possibly be obtained in some cases from the relative position of maximum radiation of their continuous spectra. Langley has shown that through the whole range of temperature on which we can experiment, and presumably at temperatures beyond, the maximum of radiation power in solid bodies gradually shifts upwards in the spectrum from the infra-red through the red and orange, and that in the sun it has reached the blue.

The defined character, as a rule, of the stellar lines of absorption suggests that the vapors producing them do not at the same time exert any strong power of general absorption. Consequently, we should probably not go far wrong, when the photosphere consists of liquid or solid particles, if we could compare select parts of the continuous spectrum between the stronger lines, or where they are fewest. It is obvious that, if extended portions of different stellar spectra were compared, their true relation would be obscured by the line-absorption.

The increase of temperature, as shown by the rise in the spectrum of the maximum of radiation, may not always be accompanied by a corresponding greater brightness of a star as estimated by the eye, which is an extremely imperfect photometric instrument. Not only is the eye blind to large regions of radiation, but even for the small range of light that we can see the visual effect varies enormously with its color. According to Prof. Langley, the same amount of energy which just enables us to perceive light in the crimson at A would in the green produce a visual effect 100,000 times greater. In the violet the proportional effect would be 1,600, in the blue 62,000, in the yellow 28,000, in the orange 14,000, and in the red 1,200. Capt. Abney's recent experiments make the sensitiveness of the eye for the green near F to be 750 times greater than for the red about C. It is for this reason, at least in part, that I suggested in 1864, and have since shown by direct observation, that the spectrum of the nebula in Andromeda, and presumably of similar nebulæ, is in appearance only wanting in the red.

The stage at which the maximum radiation is in the green, corresponding to the eye's greatest sensitiveness, would be that in which it could be most favorably measured by eye photometry. As the maximum rose into the violet and beyond, the star would increase in visual brightness, but not in proportion to the increase of energy radiated by it.

The brightness of a star would be affected by the nature of the substance by which the light was chiefly emitted. In the laboratory solid carbon exhibits the highest emissive power. A stellar stage in which radiation comes, to a large extent, from a photosphere of the solid particles of this substance would be favorable for great brilliancy. Though the stars are built up of matter essentially similar to that of the sun, it does not follow that the proportion of the different elements is everywhere the same. It may be that the substances condensed in the pho-

tospheres of different stars may differ in their emissive powers, but probably not to a great extent.

All the heavenly bodies are seen by us through the tinted medium of our atmosphere. According to Langley the solar stage of stars is not really yellow, but, even as gauged by our imperfect eyes, would appear bluish-white if we could free ourselves from the deceptive influences of our surroundings.

From these considerations it follows that we can scarcely infer the evolutional stages of the stars from a simple comparison of their eye magnitudes. We should expect the white stars to be, as a class, less dense than the stars in the solar stage. As great mass might bring in the solar type of spectrum at a relatively earlier time, some of the brightest of these stars may be very massive, and brighter than the sun—for example, the brilliant star Arcturus. For these reasons the solar stars should not only be denser than the white stars, but perhaps, as a class, surpass them in mass and eye brightness.

It has been shown by Lane that, so long as a condensing gaseous mass remains subject to the laws of a purely gaseous body its temperature will continue to rise.

The greater or less breadth of the lines of absorption of hydrogen in the white stars may be due to variations of the depth of the hydrogen in the line of sight, arising from the causes which have been discussed. At the sides of the lines the absorption and emission are feebler than in the middle, and would come out more strongly with a greater thickness of gas.

The diversities among the white stars are nearly as numerous as the individuals of the class. Time does not permit me to do more than to record that, in addition to the three sub-classes into which they have been divided by Vogel, Scheiner has recently investigated minor differences as suggested by the character of the third line of hydrogen near G. He has pointed out, too, that so far as his observations go the white stars in the constellation of Orion stand alone, with the exception of Algol, in possessing a dark line in the blue which has apparently the same position as a bright line in the great nebula of the same constellation; and Pickering finds in his photographs of the spectra of these stars dark lines corresponding to the principal lines of the bright-line stars, and the planetary nebulæ with the exception of the chief nebular line. The association of white stars with nebular matter in Orion, in the Pleiades, in the region of the Milky Way, and in other parts of the heavens, may be regarded as falling in with the view that I have taken.

In the stars possibly farther removed from the white class than our sun, belonging to the first division of Vogel's third class, which are distinguished by absorption bands with their stronger edge toward the blue, the hydrogen lines are narrower than in the solar spectrum. In these stars the density gradient is probably still more rapid, the

depth of hydrogen may be less, and possibly the hydrogen molecules may be affected by a larger number of encounters with dissimilar molecules. In some red stars with dark hydro-carbon bands, the hydrogen lines have not been certainly observed; if they are really absent it may be because the temperature has fallen below the point at which hydrogen can exert its characteristic absorption; besides, some hydrogen will have united with the carbon. The coming in of the hydro-carbon bands may indicate a later evolutional stage, but the temperature may still be high, as acetylene can exist in the electric arc.

A number of small stars more or less similar to those which are known by the names of their discoverers, Wolf and Rayet, have been found by Pickering in his photographs. These are remarkable for several brilliant groups of bright lines, including frequently the hydrogen lines and the line $D_3$, upon a continuous spectrum strong in blue and violet rays, in which are also dark lines of absorption. As some of the bright groups appear in his photographs to agree in position with corresponding bright lines in the planetary nebulæ, Pickering suggests that these stars should be placed in one class with them, but the brightest nebular line is absent from these stars. The simplest conception of their nature would be that each star is surrounded by a nebula, the bright groups being due to the gaseous matter outside the star. Mr. Roberts however has not been able to bring out any indication of nebulosity by prolonged exposure. The remarkable star $\eta$ Argûs may belong to this class of the heavenly bodies.

*Gaseous Nebulæ.*—In the nebulæ the elder Herschel saw portions of the fiery mist or "shining fluid" out of which the heavens and the earth had been slowly fashioned. For a time this view of the nebulæ gave place to that which regarded them as external galaxies, cosmical "sand heaps," too remote to be resolved into separate stars; though indeed, in 1858, Mr. Herbert Spencer showed that the observations of nebulæ up to that time were really in favor of an evolutional progress.

In 1864, I brought the spectroscope to bear upon them; the bright lines which flashed upon the eye showed the source of the light to be glowing gas, and so restored these bodies to what is probably their true place, as an early stage of sidereal life.

At that early time our knowledge of stellar spectra was small. For this reason partly, and probably also under the undue influence of theological opinions then widely prevalent, I unwisely wrote in my original paper in 1864, "that in these objects we no longer have to do with a special modification of our own type of sun, but find ourselves in presence of objects possessing a distinct and peculiar plan of structure." Two years later, however, in a lecture before this Association, I took a truer position. "Our views of the universe," I said, "are undergoing important changes; let us wait for more facts, with minds unfettered by any dogmatic theory, and therefore free to receive the teaching, whatever it may be, of new observations."

Let us turn aside for a moment from the nebulæ in the sky to the conclusions to which philosophers had been irresistibly led by a consideration of the features of the solar system. We have before us in the sun and planets obviously not a haphazard aggregation of bodies, but a system resting upon a multitude of relations pointing to a common physical cause. From these considerations Kant and Laplace formulated the nebular hypothesis, resting it on gravitation alone, for at that time the science of the conservation of energy was practically unknown. These philosophers showed how, on the supposition that the space now occupied by the solar system was once filled by a vaporous mass, the formation of the sun and planets could be reasonably accounted for.

By a totally different method of reasoning, modern science traces the solar system backward step by step to a simlar state of things at the beginning. According to Helmholtz, the sun's heat is maintained by the contraction of his mass, at the rate of about 220 feet a year. Whether at the present time the sun is getting hotter or colder we do not certainly know. We can reason back to the time the sun was sufficiently expanded to fill the whole space occupied by the solar system, and was reduced to a great glowing nebula. Though man's life, the life of the race perhaps, is too short to give us direct evidence of any distinct stages of so august a process, still the probability is great that the nebular hypothesis, especially in the more precise form given to it by Roche, does represent broadly, notwithstanding some difficulties, the succession of events through which the sun and planets have passed.

The nebular hypothesis of Laplace requires a rotating mass of fluid which at successive epochs became unstable from excess of motion, and left behind rings, or more probably perhaps lumps, of matter from the equatorial regions.

The difficulties to which I have referred have suggested to some thinkers a different view of things, according to which it is not necessary to suppose that one part of the system gravitationally supports another. The whole may consist of a congeries of discrete bodies even if these bodies be the ultimate molecules of matter. The planets may have been formed by the gradual accretion of such discrete bodies. On the view that the material of the condensing solar system consisted of separate particles or masses, we have no longer the fluid pressure which is an essential part of Laplace's theory. Faye, in his theory of evolution from meteorites, has to throw over this fundamental idea of the nebular hypothesis, and he formulates instead a different succession of events, in which the outer planets were formed last; a theory which has difficulties of its own.

Prof. George Darwin has recently shown, from an investigation of the mechanical conditions of a swarm of meteorites, that on certain assumptions a meteoric swarm might behave as a coarse gas, and in this way bring back the fluid pressure exercised by one part of the

system on the other, which is required by Laplace's theory. One chief assumption consists in supposing that such inelastic bodies as meteoric stones might attain the effective elasticity of a high order which is necessary to the theory through the sudden volatilization of a part of their mass at an encounter, by which what is virtually a violent explosive is introduced between the two colliding stones. Prof. Darwin is careful to point out that it must necessarily be obscure as to how a small mass of solid matter can take up a very large amount of energy in a small fraction of a second.

Any direct indications from the heavens themselves, however slight, are of so great value that I should, perhaps, in this connection call attention to a recent remarkable photograph, by Mr. Roberts, of the great nebula in Andromeda. On this plate we seem to have presented to us some stage of cosmical evolution on a gigantic scale. The photograph shows a sort of whirlpool disturbance of the luminous matter which is distributed in a plane inclined to the line of sight, in which a series of rings of bright matter separated by dark spaces, greatly foreshortened by perspective, surround a large, undefined central mass. We are ignorant of the parallax of this nebula, but there can be little doubt that we are looking upon a system very remote, and therefore of a magnitude great beyond our power of adequate comprehension. The matter of this nebula, in whatever state it may be, appears to be distributed, as in so many other nebulæ, in rings or spiral streams, and to suggest a stage in a succession of evolutional events not inconsistent with that which the nebular hypothesis requires. To liken this object more directly to any particular stage in the formation of the solar system would be "to compare things great with small," and might be indeed to introduce a false analogy; but, on the other hand, we should err through an excess of caution if we did not accept the remarkable features brought to light by this photograph as a presumptive indication of a progress of events in cosmical history following broadly upon the lines of Laplace's theory.

The old view of the original matter of the nebulæ, that it consisted of a "fiery mist,"

> a tumultuous cloud
> Instinct with fire and niter.

fell at once with the rise of the science of thermodynamics. In 1854 Helmholtz showed that the supposition of an original fiery condition of the nebulous stuff was unnecessary, since in the mutual gravitation of widely separated matter we have a store of potential energy sufficient to generate the high temperature of the sun and stars. We can scarcely go wrong in attributing the light of the nebulæ to the conversion of the gravitational energy of shrinkage into molecular motion.

The idea that the light of comets and of nebulæ may be due to a succession of ignited flashes of gas from the encounters of meteoric stones

was suggested by Prof. Tait, and was brought to the notice of this Association in 1871 by Sir William Thomson in his presidential address.

The spectrum of the bright-line nebulæ is certainly not such a spectrum as we should expect from the flashing by collisions of meteorites similar to those which have been analyzed in our laboratories. The strongest lines of the substances which in the case of such meteorites would first show themselves, iron, sodium, magnesium, nickel, etc., are not those which distinguish the nebular spectrum. On the contrary, this spectrum is chiefly remarkable for a few brilliant lines, very narrow and defined, upon a background of a faint continuous spectrum, which contains numerous bright lines, and probably some lines of absorption.

The two most conspicuous lines have not been interpreted; for though the second line falls near, it is not coincident with a strong double line of iron. It is hardly necessary to say that though the near position of the brightest line to the bright double line of nitrogen, as seen in a small spectroscope in 1864, naturally suggested at that early time the possibility of the presence of this element in the nebulæ, I have been careful to point out, to prevent misapprehension, that in more recent years the nitrogen line and subsequently a lead line have been employed by me solely as fiducial points of reference in the spectrum.

The third line we know to be the second line of the first spectrum of hydrogen. Mr. Keeler has seen the first hydrogen line in the red, and photographs show that this hydrogen spectrum is probably present in its complete form, or nearly so, as we first learnt to know it in the absorption spectrum of the white stars.

We are not surprised to find associated with it the line $D_3$, near the position of the absent sodium lines, probably due to the atom of some unknown gas, which in the sun can only show itself in the outbursts of highest temperature, and for this reason does not reveal itself by absorption in the solar spectrum.

It is not unreasonable to assume that the two brightest lines, which are of the same order, are produced by substances of a similar nature, in which a vibratory motion corresponding to a very high temperature is also necessary. These substances, as well as that represented by the line $D_3$, may be possibly some of the unknown elements which are wanting in our terrestrial chemistry between hydrogen and lithium, unless indeed $D_3$ be on the lighter side of hydrogen.

In the laboratory we must have recourse to the electric discharge to bring out the spectrum of hydrogen; but in a vacuum tube, though the radiation may be great, from the relative fewness of the luminous atoms or molecules or from some other cause, the temperature of the gas as a whole may be low.

On account of the large extent of the nebulæ, a comparatively smal number of luminous molecules or atoms would probably be sufficient

to make the nebulæ as bright as they appear to us. On such an assumption the average temperature may be low, but the individual particles, which by their encounters are luminous, must have motions corresponding to a very high temperature, and in this sense be extremely hot.

In such diffuse masses, from the great mean length of free path, the encounters would be rare but correspondingly violent, and tend to bring about vibrations of comparatively short period, as appears to be the case if we may judge by the great relative brightness of the more refrangible lines of the nebular spectrum.

Such a view may, perhaps, reconcile the high temperature, which the nebular spectrum undoubtedly suggests, with the much lower mean temperature of the gaseous mass which we should expect at so early a stage of condensation, unless we assume a very enormous mass, or that the matter coming together had previously considerable motion or considerable molecular agitation.

The inquisitiveness of the human mind does not allow us to remain content with the interpretation of the present state of the cosmical masses, but suggests the question—

What see'st thou else
In the dark backward and abysm of time?

What was the original state of things? how has it come about that by the side of aging worlds we have nebulæ in a relatively younger stage? Have any of them received their birth from dark suns, which have collided into new life, and so belong to a second or later generation of the heavenly bodies?

During the short historic period, indeed, there is no record of such an event; still it would seem to be only through the collision of dark suns, of which the number must be increasing, that a temporary rejuvenescence of the heavens is possible, and by such ebbings and flowings of stellar life that the inevitable end to which evolution in its apparently uncompensated progress is carrying us can, even for a little, be delayed.

We can not refuse to admit as possible such an origin for nebulæ.

In considering, however, the formation of the existing nebulæ we must bear in mind that, in the part of the heavens within our ken, the stars still in the early and middle stages of evolution exceed greatly in number those which appear to be in an advanced condition of condensation. Indeed, we find some stars which may be regarded as not far advanced beyond the nebular condition.

It may be that the cosmical bodies which are still nebulous owe their later development to some conditions of the part of space where they occur, such as, conceivably, a greater original homogeneity, in consequence of which condensation began less early. In other parts of space condensation may have been still further delayed, or even have not yet

begun. It is worthy of remark that these nebulæ group themselves about the Milky Way, where we find a preponderance of the white-star type of stars, and almost exclusively the bright-line stars which Pickering associates with the planetary nebulæ. Further, Dr. Gill concludes, from the rapidity with which they impress themselves upon the plate, that the fainter stars of the Milky Way also, to a large extent, belong to this early type of stars. At the same time other types of stars occur also over this region, and the red hydrocarbon stars are found in certain parts; but possibly these stars may be before or behind the Milky Way, and not physically connected with it.

If light matter be suggested by the spectrum of these nebulæ, it may be asked further, as a pure speculation, whether in them we are witnessing possibly a later condensation of the light matter which had been left behind, at least in a relatively greater proportion, after the first growth of worlds into which the heavier matter condensed, though not without some entanglement of the lighter substances. The wide extent and great diffuseness of this bright-line nebulosity over a large part of the constellation of Orion may be regarded perhaps as pointing in this direction. The diffuse nebulous matter streaming round the Pleiades may possibly be another instance, though the character of its spectrum has not yet been ascertained.

In the planetary nebulæ, as a rule, there is a sensible increase of the faint continuous spectrum, as well as a slight thickening of the bright lines toward the center of the nebula, appearances which are in favor of the view that these bodies are condensing gaseous masses.

Prof. G. Darwin, in his investigation of the equilibrium of a rotating mass of fluid, found, in accordance with the independent researches of Poincaré, that when a portion of the central body becomes detached through increasing angular velocity, the portion should bear a far larger ratio to the remainder than is observed in the planets and satellites of the solar system, even taking into account heterogeneity from the condensation of the parent mass.

Now this state of things, in which the masses though not equal are of the same order, does seem to prevail in many nebulæ, and to have given birth to a large class of binary stars. Mr. See has recently investigated the evolution of bodies of this class, and points out their radical differences from the solar system in the relatively large mass-ratios of the component bodies, as well as in the high eccentricities of their orbits, brought about by tidal friction, which would play a more important part in the evolution of such systems.

Considering the large number of these bodies, he suggests that the solar system should perhaps no longer be regarded as representing celestial evolution in its normal form—

> A goodly Paterne to whose perfect mould
> He fashioned them - - - —

but rather as modified by conditions which are exceptional.

It may well be that in the very early stages condensing masses are subject to very different conditions, and that condensation may not always begin at one or two centers, but sometimes set in at a large number of points, and proceed in the different cases along very different lines of evolution.

*Invisible Motions revealed by the Spectroscope.*—Besides its more direct use in the chemical analysis of the heavenly bodies, the spectroscope has given to us a great and unexpected power of advance along the lines of the older astronomy. In the future a higher value may indeed be placed upon this indirect use of the spectroscope than upon its chemical revelations.

By no direct astronomical methods could motions of approach or of recession of the stars be even detected, much less could they be measured. A body coming directly toward us or going directly from us appears to stand still. In the case of the stars we can receive no assistance from change of size or of brightness. The stars show no true disks in our instruments, and the nearest of them is so far off that if it were approaching us at the rate of a hundred miles in a second of time, a whole century of such rapid approach would not do more than increase its brightness by the one-fortieth part.

Still it was only too clear that so long as we were unable to ascertain directly those components of the stars' motions which lie in the line of sight, the speed and direction of the solar motion in space, and many of the great problems of the constitution of the heavens, must remain more or less imperfectly known. Now the spectroscope has placed in our hands this power, which, though so essential, appeared almost in the nature of things to lie forever beyond our grasp; it enables us to measure directly, and under favorable circumstances to within a mile per second, or even less, the speed of approach or of recession of a heavenly body. This method of observation has the great advantage for the astronomer of being independent of the distance of the moving body, and is therefore as applicable and as certain in the case of a body on the extreme confines of the visible universe (so long as it is bright enough), as in the case of a neighboring planet.

Doppler had suggested as far back as 1841, that the same principle on which he had shown that a sound should become sharper or flatter if there were an approach or a recession between the ear and the source of the sound, would apply equally to light; and he went on to say that the difference of color of some of the binary stars might be produced in this way by their motions. Doppler was right in that the principle is true in the case of light, but he was wrong in the particular conclusion which he drew from it. Even if we suppose a star to be moving with a sufficiently enormous velocity to alter sensibly its color to the eye, no such change would actually be seen, for the reason that the store of invisible light beyond both limits of the visible spectrum,

the blue and the red, would be drawn upon, and light-waves invisible to us would be exalted or degraded so as to take the place of those raised or lowered in the visible region, and the color of the star would remain unchanged. About eight years later, Fizeau pointed out the importance of considering the individual wave-lengths of which white light is composed. As soon however as we had learned to recognize the lines of known substances in the spectra of the heavenly bodies, Doppler's principle became applicable as the basis of a new and most fruitful method of investigation. The measurement of the small shift of the celestial lines from their true positions, as shown by the same lines in the spectrum of a terrestrial substance, gives to us the means of ascertaining directly in miles per second the speed of approach or of recession of the heavenly body from which the light has come.

An account of the first application of this method of research to the stars, which was made in my observatory in 1868, was given by Sir Gabriel Stokes from this chair at the meeting at Exeter in 1869. The stellar motions determined by me were shortly after confirmed by Prof. Vogel in the case of Sirius, and in the case of other stars by Mr. Christie, now astronomer-royal, at Greenwich; but, necessarily, in consequence of the inadequacy of the instruments then in use for so delicate an inquiry, the amounts of these motions were but approximate.

The method was shortly afterwards taken up systematically at Greenwich and at the Rugby Observatory. It is to be greatly regretted that, for some reasons, the results have not been sufficiently accordant and accurate for a research of such exceptional delicacy. On this account probably, as well as that the spectroscope at that early time had scarcely become a familiar instrument in the observatory, astronomers were slow in availing themselves of this new and remarkable power of investigation. That this comparative neglect of so truly wonderful a method of ascertaining what was otherwise outside our powers of observation has greatly retarded the progress of astronomy during the last fifteen years, is but too clearly shown by the brilliant results which within the last couple of years have followed fast upon the recent masterly application of this method by photography at Potsdam, and by eye with the needful accuracy at the Lick Observatory. At last this use of the spectroscope has taken its true place as one of the most potent methods of astronomical research. It gives us the motions of approach and of recession, not in angular measures, which depend for their translation into actual velocities upon separate determinations of parallactic displacements, but at once in terrestrial units of distance.

This method of work will doubtless be very prominent in the astronomy of the near future, and to it probably we shall have to look for the more important discoveries in sideral astronomy which will be made during the coming century.

In his recent application of photography to this method of determining celestial motions, Prof. Vogel, assisted by Dr. Scheiner, consider-

ing the importance of obtaining the spectrum of as many stars as possible on an extended scale without an exposure inconveniently long, wisely determined to limit the part of the spectrum on the plate to the region for which the ordinary silver-bromide gelatine plates are most sensitive,—namely, to a small distance on each side of G,—and to employ as the line of comparison the hydrogen line near G, and recently also certain lines of iron. The most minute and complete mechanical arrangements were provided for the purpose of securing the absolute rigidity of the comparison spectrum relatively to that of the star, and for permitting temperature adjustments and other necessary ones to be made.

The perfection of these spectra is shown by the large number of lines, no fewer that two hundred and fifty in the case of Capella, within the small region of the spectrum on the plate. Already the motions of about fifty stars have been measured with an accuracy, in the case of the larger number of them, of about an English mile per second.

At the Lick Observatory it has been shown that observations can be made directly by eye with an accuracy equally great. Mr. Keeler's brilliant success has followed in great measure from the use of the third and fourth spectra of a grating 14,438 lines to the inch. The marvellous accuracy attainable in his hands on a suitable star is shown by observations on three nights of the star Arcturus, the largest divergence of his measures being not greater than six-tenths of a mile per second, while the mean of the three nights' work agreed with the mean of five photographic determinations of the same star at Potsdam to within one-tenth of an English mile. These are determinations of the motions of a sun so stupendously remote that even the method of parallax practically fails to fathom the depth of intervening space, and by means of light-waves which have been, according to Elkin's nominal parallax, nearly two hundred years upon their journey.

Mr. Keeler, with his magnificent means, has accomplished a task which I attempted in vain in 1874, with the comparatively poor appliances at my disposal, of measuring the motions in the line of sight of some of the planetary nebulæ. As the stars have considerable motions in space, it was to be expected that nebulæ should possess similar motions, for the stellar motions must have belonged to the nebulæ out of which they have been evolved. My instrumental means, limiting my power of detection to motions greater than 25 miles per second, were insufficient. Mr. Keeler has found in the examination of ten nebulæ motions varying from 2 miles to 27 miles, with one exceptional motion of nearly 40 miles.

For the nebula of Orion, Mr. Keeler finds a motion of recession of about 10 miles a second. Now, this motion agrees closely with what it should appear to have from the drift of the solar system itself, so far as it has been possible at present to ascertain the probable velocity of the sun in space. This grand nebula, of vast extent and of extreme

tenuity, is pobably more nearly at rest relatively to the stars of our system than any other celestial object we know; still it would seem more likely that even here we have some motion, small though it may be, than that the motions of the matter of which it is formed were so absolutely balanced as to leave this nebula in the unique position of absolute immobility in the midst of whirling and drifting suns and systems of suns.

The spectroscopic method of determining celestial motions in the line of sight has recently become fruitful in a new but not altogether unforeseen direction, for it has, so to speak, given us a separating power far beyond that of any telescope the glassmaker and the optician could construct, and so enabled us to penetrate into mysteries hidden in stars apparently single, and altogether unsuspected of being binary systems. The spectroscope has not simply added to the list of the known binary stars, but has given to us for the first time a knowledge of a new class of stellar systems, in which the components are in some cases of nearly equal magnitude, and in close proximity, and are revolving with velocities greatly exceeding the planetary velocities of our system.

The K line in the photographs of Mizar, taken at the Harvard College Observatory, was found to be double at intervals of fifty-two days. The spectrum was therefore not due to a single source of light, but to the combined effect of two stars moving periodically in opposite directions in the line of sight. It is obvious that if two stars revolve round their common centre of gravity in a plane not perpendicular to the line of sight, all the lines in a spectrum common to the two stars will appear alternately single or double.

In the case of Mizar and the other stars to be mentioned, the spectroscopic observations are not as yet extended enough to furnish more than an approximate determination of the elements of their orbits.

Mizar especially, on account of its relatively long period—about one hundred and five days—needs further observations. The two stars are moving each with a velocity of about 50 miles a second, probably in elliptical orbits, and are about 143,000,000 miles apart. The stars, of about equal brightness, have together a mass about forty times as great as that of our sun.

A similar doubling of the lines showed itself in the Harvard photographs of $\beta$ Aurigæ at the remarkably close interval of almost exactly two days, indicating a period of revolution of about four days. According to Vogel's later observations, each star has a velocity of nearly 70 miles a second, the distance between the stars being little more than 7,500,000 miles, and the mass of the system 4.7 times that of the sun. The system is approaching us at the speed of about 16 miles a second.

The telescope could never have revealed to us double stars of this order. In the case of $\beta$ Aurigæ, combining Vogel's distance with Pritchard's recent determination of the star's parallax, the greatest angular separation of the stars as seen from the earth would be one

two-hundredth part of a second of arc, and therefore very far too small for the highest powers of the largest telescopes. If we take the relation of aperture to separating power usually accepted, an object glass of about 80 feet in diameter would be needed to resolve this binary star. The spectroscope, which takes no note of distance, magnifies, so to speak, this minute angular separation 4,000 times; in other words, the doubling of the lines, which is the phenomenon that we have to observe, amounts to the easily measurable quantity of 20 seconds of arc.

There were known, indeed, variable stars of short period, which it had been suggested might be explained on the hypothesis of a dark body revolving about a bright sun in a few days, but this theory was met by the objection that no such systems of closely revolving suns were known to exist.

The Harvard photographs of which we have been speaking were taken with a slitless form of spectroscope, the prisms being placed, as originally by Fraunhofer, before the object glass of the telescope. This method, though it possesses some advantages, has the serious drawback of not permitting a direct comparison of the star's spectrum with terrestrial spectra. It is obviously unsuited to a variable star like Algol, where one star only is bright, for in such a case there would be no doubling of the lines, but only a small shift to and fro of the lines of the bright star as it moved in its orbit alternately toward and from our system, which would need for its detection the fiducial positions of terrestrial lines compared directly with them.

For such observations the Potsdam spectograph was well adapted. Prof. Vogel found that the bright star of Algol did pulsate backwards and forwards in the visual direction in a period corresponding to the known variation of its light. The explanation which had been suggested for the star's variability, that it was partially eclipsed at regular intervals of 68.8 hours by a dark companion large enough to cut off nearly five-sixths of its light, was therefore the true one. The dark companion, no longer able to hide itself by its obscureness, was brought out into the light of direct observations by means of its gravitational effects.

Seventeen hours before minimum, Algol is receding at the rate of about 24½ miles a second, while seventeen hours after minimum it is found to be approaching with a speed of about 28½ miles. From these data, together with those of the variation of its light, Vogel found, on the assumption that both stars have the same density, that the companion, nearly as large as the sun, but with about one-fourth his mass, revolves with a velocity of about 55 miles a second. The bright star, of about twice the size and mass, moves about the common center of gravity with the speed of about 26 miles a second. The system of the two stars, which are about 3,250,000 of miles apart, considered as a whole, is approaching us with a velocity of 2.4 miles a second. The great difference in luminosity of the two stars, not less than fifty times,

suggests rather that they are in different stages of condensation, and dissimilar in density.

It is obvious that if the orbit of a star with an obscure companion is inclined to the line of sight, the companion will pass above or below the bright star, and produce no variation of its light. Such systems may be numerous in the heavens. In Vogel's photographs, Spica, which is not variable, by a small shifting of its lines reveals a backward and forward periodical pulsation due to orbital motion. As the pair whirl round their common center of gravity, the bright star is sometimes advancing, at others receding. They revolve in about four days, each star moving with a velocity of about 56 miles a second in an orbit probably nearly circular, and possess a combined mass of rather more than two and a half times that of the sun. Taking the most probable value for the star's parallax, the greatest angular separation of the stars would be far too small to be detected with the most powerful telescopes.

If in a close double star the fainter companion is of the white-star type, while the bright star is solar in character, the composite spectrum would be solar with the hydrogen lines unusually strong. Such a spectrum would in itself afford some probability of a double origin, and suggest the existence of a companion star.

In the case of a true binary star the orbital motions of the pair would reveal themselves in a small periodical swaying of the hydrogen lines relatively to the solar ones.

Prof. Pickering considers that his photographs show ten stars with composite spectra; of these, five are known to be double. The others are: $\tau$ Persei, $\zeta$ Aurigæ, $\delta$ Sagittarii, 31 Ceti, and $\beta$ Capricorni. Perhaps $\beta$ Lyræ should be added to this list.

In his recent classical work on the rotation of the sun, Dunér has not only determined the solar rotation for the equator but for different parallels of latitude up to 75°. The close accordance of his results shows that these observations are sufficiently accurate to be discussed with the variation of the solar rotation for different latitudes which had been determined by the older astronomical methods from the observations of the solar spots.

*Spectroscopic Photography.*—Though I have already spoken incidentally of the invaluable aid which is furnished by photography in some of the applications of the spectroscope to the heavenly bodies, the new power which modern photography has put into the hands of the astronomer is so great, and has led already, within the last few years, to new acquisitions of knowledge of such vast importance, that it is fitting that a few sentences should be specially devoted to this subject.

Photography is no new discovery, being about half a century old; it may excite surprise, and indeed possibly suggest some apathy on the part of astronomers, though the suggestion of the application of photography to the heavenly bodies dates from the memorable occasion

when, in 1839, Arago, announcing to the Académie de Sciences the great discovery of Niepce and Daguerre, spoke of the possibility of taking pictures of the sun and moon by the new process, yet that it is only within a few years that notable advances in astronomical methods and discovery have been made by its aid.

The explanation is to be found in the comparative unsuitability of the earlier photographic methods for use in the observatory. In justice to the earlier workers in astronomical photography, among whom Bond, De la Rue, J. W. Draper, Rutherfurd, Gould, hold a foremost place, it is needful to state clearly that the recent great successes in astronomical photography are not due to greater skill, nor, to any great extent, to superior instruments, but to the very great advantages which the modern gelatin dry plate possesses for use in the observatory over the methods of Daguerre, and even over the wet collodion film on glass, which, though a great advance on the silver plate, went but a little way towards putting into the hands of the astronomer a photograhic surface adapted fully to his wants.

The modern silver-bromide gelatine plate, except for its grained texture, meets the needs of the astronomer at all points. It possesses extreme sensitiveness; it is always ready for use; it can be placed in any position; it can be exposed for hours; lastly, it does not need immediate development, and for this reason can be exposed again to the same object on succeeding nights, so as to make up by several installments, as the weather may permit, the total time of exposure which is deemed necessary.

Without the assistance of photography, however greatly the resources of genius might overcome the optical and mechanical difficulties of constructing large telescopes, the astronomer would have to depend in the last resource upon his eye. Now we can not by the force of continued looking bring into view an object too feebly luminous to be seen at the first and keenest moment of vision. But the feeblest light which falls upon the plate is not lost, but is taken in and stored up continuously. Each hour the plate gathers up 3,600 times the light-energy which it received during the first second. It is by this power of accumulation that the photographic plate may be said to increase, almost without limit, though not in separating power, the optical means at the disposal of the astronomer for the discovery or the observation of faint objects.

Two principal directions may be pointed out in which photography is of great service to the astronomer. It enables him within the comparatively short time of a single exposure to secure permanently with great exactness the relative positions of hundreds or even of thousands of stars, or the minute features of nebulæ or other objects, or the phenomena of a passing eclipse, a task which by means of the eye and hand could only be accomplished, if done at all, after a very great expenditure of time and labor. Photography puts it in the power of the

astronomer to accomplish in the short span of his own life, and so enter into their fruition, great works which otherwise must have been passed on by him as a heritage of labor to succeeding generations.

The second great service which photography renders is not simply an aid to the powers the astronomer already possesses. On the contrary, the plate, by recording light-waves which are both too small and too large to excite vision in the eye, brings him into a new region of knowledge, such as the infra-red and the ultra-violet parts of the spectrum, which must have remained forever unknown but for artificial help.

The present year will be memorable in astronomical history for the practical beginning of the Photographic Chart and Catalogue of the Heavens, which took their origin in an international conference which met in Paris in 1887, by the invitation of M. l'Amiral Mouchez, director of the Paris Observatory.

The richness in stars down to the ninth magnitude of the photographs of the comet of 1882 taken at the Cape Observatory under the superintendence of Dr. Gill, and the remarkable star charts of the Brothers Henry which followed two years later, astonished the astronomical world. The great excellence of these photographs, which was due mainly to the superiority of the gelatine plate, suggested to these astronomers a complete map of the sky, and a little later gave birth in the minds of the Paris astronomers to the grand enterprise of an International Chart of the Heavens. The actual beginning of the work this year is in no small degree due to the great energy and tact with which the director of the Paris Observatory has conducted the initial steps, through the many delicate and difficult questions which have unavoidably presented themselves in an undertaking which depends upon the harmonious working in common of many nationalities, and of no fewer than eighteen observatories in all parts of the world. The three years since 1887 have not been too long for the detailed organization of this work, which has called for several elaborate preliminary investigations on special points in which our knowledge was insufficient, and which have been ably carried out by Profs. Vogel and Bakhuyzen, Dr. Trépied, Dr. Scheiner, Dr. Gill, the astronomer-royal, and others. Time also was required for the construction of the new and special instruments.

The decisions of the conference in their final form provide for the construction of a great photographic chart of the heavens with exposures corresponding to forty minutes' exposure at Paris, which it is expected will reach down to stars of about the fourteenth magnitude. As each plate is to be limited to 4 square degrees, and as each star, to avoid possible errors, is to appear on two plates, over 22,000 photographs will be required. For the more accurate determination of the positions of the stars, a *réseau* with lines at distances of 5 millimeters apart is to be previously impressed by a faint light upon the plate, so

that the image of the *réseau* will appear together with the images of the stars when the plate is developed. This great work will be divided according to their latitudes among eighteen observatories provided with similar instruments, though not necessarily constructed by the same maker. Those in the British dominions and at Tacubaya have been constructed by Sir Howard Grubb.

Besides the plates to form the great chart, a second set of plates for a catalogue is to be taken with a shorter exposure, which will give stars to the eleventh magnitude only. These plates, by a recent decision of the permanent committee, are to be pushed on as accurately as possible, though as far as may be practicable plates for the chart are to be taken concurrently. Photographing the plates for the catalogue is but the first step in this work, and only supplies the data for the elaborate measurements which have to be made, which are however less laborious than would be required for a similar catalogue without the aid of photography.

Already Dr. Gill has nearly brought to conclusion, with the assistance of Prof. Kapteyn, a preliminary photograhic survey of the southern heavens.

With an exposure sufficiently long for the faintest stars to impress themselves upon the plate, the accumulating action still goes on for the brighter stars, producing a great enlargement of their images from optical and photographic causes. The question has occupied the attention of many astronomers, whether it is possible to find a law connecting the diameters of these more or less over-exposed images with the relative brightness of the stars themselves. The answer will come out undoubted in the affirmative, though at present the empirical formulæ which have been suggested for this purpose differ from each other. Capt. Abney proposes to measure the total photographic action, including density as well as size, by the obstruction which the stellar image offers to light.

A further question follows as to the relation which the photographic magnitudes of stars bear to those determined by eye. Visual magnitudes are the physiological expression of the eye's integration of that part of the star's light which extends from the red to the blue. Photographic magnitudes represent the plate's integration of another part of the star's light, namely, from a little below where the power of the eye leaves off in the blue to where the light is cut off by the glass, or is greatly reduced by want of proper corrections when a refracting telescope is used. It is obvious that the two records are taken by different methods in dissimilar units of different parts of the star's light. In the case of certain colored stars the photographic brightness is very different from the visual brightness; but in all stars, changes, especially of a temporary character, may occur in the photographic or the visual region, unaccompanied by a similar change in the other part of the spectrum. For these reasons it would seem desirable that the two sets

of magnitudes should be tabulated independently, and be regarded as supplementary of each other.

The determination of the distances of the fixed stars from the small apparent shift of their positions, when viewed from widely separated positions of the earth in its orbit, is one of the most refined operations of the observatory. The great precision with which this minute angular quantity—a fraction of a second only—has to be measured, is so delicate an operation with the ordinary micrometer, though, indeed, it was with this instrument that the classical observations of Sir Robert Ball were made, that a special instrument, in which the measures are made by moving the two halves of a divided object glass, known as a heliometer, has been pressed into this service, and quite recently, in the skillful hands of Dr. Gill and Dr. Elkin, has largely increased our knowledge in this direction.

It is obvious that photography might be here of great service, if we could rely upon measurements of photographs of the same stars taken at suitable intervals of time. Prof. Pritchard, to whom is due the honor of having opened this new path, aided by his assistants, has proved by elaborate investigations that measures for parallax may be safely made upon photographic plates, with, of course, the advantages of leisure and repetition; and he has already by this method determined the parallax for twenty-one stars with an accuracy not inferior to that of values previously obtained by purely astronomical methods.

The remarkable successes of astronomical photography, which depend upon the plate's power of accumulation of a very feeble light acting continuously through an exposure of several hours, are worthy to be regarded as a new revelation. The first chapter opened when, in 1880, Dr. Henry Draper obtained a picture of the nebula of Orion; but a more important advance was made in 1883, when Dr. Common, by his photographs, brought to our knowledge details and extensions of this nebula, hitherto unknown. A further disclosure took place in 1885, when the brothers Henry showed for the first time in great detail the spiral nebulosity issuing from the bright star Maia of the Pleiades, and shortly afterwards nebulous streams about the other stars of this group. In 1886 Mr. Roberts, by means of a photograph to which three hours' exposure had been given, showed the whole background of this group to be nebulous. In the following year Mr. Roberts more than doubled for us the great extension of the nebular region which surrounds the trapezium in the constellation of Orion. By his photographs of the great nebula in Andromeda he has shown the true significance of the dark canals which had been seen by the eye. They are in reality spaces between successive rings of bright matter, which appeared nearly straight owing to the inclination in which they lie relatively to us. These bright rings surround an undefined central luminous mass. I have already spoken of this photograph.

Some recent photographs by Mr. Russell show that the great rift in

the Milky Way in Argus, which to the eye is void of stars, is in reality uniformily covered with them. Also, quite recently, Mr. George Hale has photographed the prominences by means of a grating, making use of the lines H and K.

*Stellar distributions.*—The heavens are richly but very irregularly inwrought with stars, the brighter stars cluster into well-known groups upon a background formed of an enlacement of streams and convoluted windings and intertwined spirals of fainter stars, which becomes richer and more intricate in the irregular rifted zone of the Milky Way.

We, who form part of the emblazonry, can only see the design distorted and confused; here crowded, there scattered, at another place superposed. The groupings due to our position are mixed up with those which are real.

Can we suppose that each luminous point has no relation to the others near it than the accidental neighborship of grains of sand upon the shore, or of particles of the wind-blown dust of the desert? Surely every star, from Sirius and Vega down to each grain of the light dust of the Milky Way, has its present place in the heavenly pattern from the slow evolving of its past. We see a system of systems, for the broad features of clusters and streams and spiral windings which mark the general design are re-produced in every part. The whole is in motion, each point shifting its position by miles every second, though from the august magnitude of their distances from us and from each other, it is only by the accumulated movements of years or of generations that some small changes of relative position reveal themselves.

The deciphering of this wonderfully intricate constitution of the heavens will be undoubtedly one of the chief astronomical works of the coming century. The primary task of the sun's motion in space, together with the motions of the brighter stars, has been already put well within our reach by the spectroscopic method of the measurement of star motions in the line of sight.

From other directions information is accumulating; from photographs of clusters and parts of the Milky Way, by Roberts, in this country, Barnard, at the Lick Observatory, and Russell, at Sydney; from the counting of stars, and the detection of their configurations by Holden and by Backhouse; from the mapping of the Milky Way by eye, at Parsonstown; from photographs of the spectra of stars, by Pickering at Harvard and in Peru, and from the exact portraiture of the heavens in the great international star chart which begins this year.

I have but touched some only of the problems of the newer side of astronomy. There are many others which would claim our attention if time permitted. The researches of the Earl of Rosse on lunar radiation, and the work on the same subject and on the sun, by Langley. Observations of lunar heat with an instrument of his own invention

by Mr. Boys; and observations of the variation of the moon's heat with its phase by Mr. Frank Very. The discovery of the ultra-violet part of the hydrogen spectrum, not in the laboratory, but from the stars. The confirmation of this spectrum by terrestrial hydrogen in part by H. W. Vogel, and in its all but complete form by Cornu, who found similar series in the ultra-violet spectra of aluminium and thallium. The discovery of a simple formula for the hydrogen series by Balmer. The important question as to the numerical spectral relationship of different substances, especially in connection with their chemical properties; and the further question as to the origin of the harmonic and other relations between the lines and the groupings of lines of spectra; on these points contributions during the past year have been made by Rudolf v. Kövesligethy, Ames, Hartley, Deslandres, Rydberg, Grünwald, Kayser and Runge, Johnstone Stoney, and others. The remarkable employment of interference phenomena by Prof. Michelson for the determination of the size, and distribution of light within them, of the images of objects which when viewed in a telescope subtend an angle less than that subtended by the light wave at a distance equal to the diameter of the objective. A method applicable not alone to celestial objects, but also to spectral lines, and other questions of molecular physics.

Along the older lines there has not been less activity; by newer methods, by the aid of larger or more accurately constructed instruments, by greater refinement of analysis, knowledge has been increased, especially in precision and minute exactness.

Astronomy, the oldest of the sciences, has more than renewed her youth. At no time in the past has she been so bright with unbounded aspirations and hopes. Never were her temples so numerous nor the crowd of her votaries so great. The British Astronomical Association formed within the year numbers already about 600 members. Happy is the lot of those who are still on the eastern side of life's meridian.

Already, alas! the original founders of the newer methods are falling out—Kirchhoff, Ångström, D'Arrest, Secchi, Draper, Becquerel; but their places are more than filled; the pace of the race is gaining, but the goal is not and never will be in sight.

Since the time of Newton our knowledge of the phenomena of nature has wonderfully increased, but man asks, perhaps more earnestly now than in his days, What is the ultimate reality behind the reality of the perceptions? Are they only the pebbles of the beach with which we have been playing? Does not the ocean of ultimate reality and truth lie beyond?

# STELLAR NUMBERS AND DISTANCES:

## BY MEANS OF PHOTOGRAPHIC STAR GAUGING.*

By Agnes M. Clerke.

The mere equal-surface counting of the stars visible with the same instrument in different sections of the sky gives results open to mis-interpretation. Admirable in itself, the method fails because it encounters what we may call "systematic errors" in the distribution of the stars. With incidental anomalies it is fully competent to deal; they should, on a large average, be mutually compensatory; but it breaks down before the clustering tendency which pervades, more or less markedly, the entire sidereal system. Not only are certain parts of space more crowded than others, but the crowded parts are related according to an obvious plan. They do *not* occur casually. Their effect is then heightened, instead of being eliminated, by multiplied observations.

The present resources of science, however, seem to offer the means of discriminating, to some extent, between real crowding and the simple extent of star-strewn space. Although the total number of the stars visible in each case with the same telescope might be precisely the same, their relative numbers, counted by magnitudes, would in all probability be very different. In a stratum, supposing the distribution of the stars equable and their size uniform, their numbers should be nearly quadrupled at each descent of a magnitude. This, of course, is an ideal law of progression which we can not expect to find anywhere strictly obeyed; but even approximate conformity to it must be held to indicate with tolerable certainty that the lessening ranks of the stars are, on the whole, at distances from us corresponding with their light. Now it *is* approximately conformed to by the stellar multitude down to the 8.9 magnitude over the general expanse of the sky, as well as over the zone of the Milky Way. But in that zone stars of the ninth and higher magnitudes very much exceed their due numerical proportions; in other words, they are physically, no less than optically, condensed.

From these circumstances two very important inferences may be derived: First, that the lower margin of the galactic aggregations lies at a distance from us corresponding roughly to the mean distance of a ninth magnitude star, costing light some fourteen hundred years of travel; next, that the aggregated objects are average stars, neither

* From *Nature*, August 8, 1889, vol. XL, pp. 344–346.

larger nor smaller than those in our nearer neighborhood. Both conclusions seem inevitable should the facts turn out, on closer investigation, to be as above stated. A regular increase in the numbers of the successive photometric orders of stars, tallying with the increased cubical contents of the successive spheres of which the radii are the theoretical mean distances of those same orders, affords strong, if not demonstrative, evidence of a corresponding real penetration of space.* And since the sequence continues unbroken down just to the ninth magnitude, we see that the galactic condensations of ninth magnitude stars can not be situated nearer to us than their brightness would lead us to suppose—can not, in other words, be stars on a lower than the ordinary level of luster.

It is tolerably certain however that the denser star clouds of the Milky Way lie far beyond ninth magnitude distance. The ground for this assertion is not the apparent minuteness of their components, but the singular fact, adverted to by Argelander, that, in the divided Milky Way, running from Cygnus to the Centaur, the shining branches are nearly on a par with the dark rift separating them as regards the distribution of stars even fainter than the ninth magnitude. The nebulous effect to the eye distinguishing the branches is then presumably due to more remote collections. As to the further limits of these we know as yet nothing, except that Herschel's gauge numbers left it to be inferred that "thinning-out" had become marked before the attainment of fourteenth magnitude distance. On these and similar subjects enlightenment may be hoped for through the judicious use of means already at hand.

For simple star-counts, we have only to substitute star-counts by magnitudes over selected areas of the sky.† The relative numbers of the photometric ranks can hardly fail to give highly valuable indications as to real distribution; provided only that the assumption of a general uniformity in the brightness of the stars be valid. Not (it need scarcely be said) of a uniformity such as to preclude any extent of individual variety; all that need be supposed is that the average size of a star remains constant throughout sidereal space. This hypothesis has far more probability in its favor than any other which could be set up instead of it; though it may receive corrections as our inquiries advance.

The photometric classification of small stars is one of the many branches of sidereal science which will henceforth be prosecuted only with the assistance of the camera. Visual methods are inadequate and insecure. Those by photography, it is true, have also their difficulties,

* The idea of determining distance by distribution seems to have presented itself to Dr. Gould in 1874. See *American Journal of Science*, vol. VIII.

† This plan was first suggested by Prof. Holden in 1883, as a mode of investigating the composition of star-groupings ("Washburn Publications," vol. II, p. 113). Counts with varied telescopic apertures gave him the numbers in the successive photometric ranks. We believe that a photographic method of determining them has since been adopted by him.

not yet completely vanquished; they will, however, evidently prove manageable. Prof. Pickering is tentatively establishing methods in photographic photometry which will doubtless before long be brought to perfection. They depend mainly upon comparisons of stellar impressions upon any given plate, exposed under known conditions, with standard impressions of standard stars obtained with varied exposures or apertures. For the purpose we have in view, accidental errors of estimation, even if very large in amount, are of no importance. What is essential is that the integrity of the series should be preserved—that the proportionate change of light from one magnitude to the next should remain invariable from the first term to the last. The realization of this aim, now virtually attained, is one of the most weighty services rendered to astronomy by the sensitive plate.

We may now describe the process of photographic star-gauging. It consists in the enumeration, by magnitudes or half magnitudes, of the stars down, say, to the fifteenth magnitude, self-pictured from distinctively situated patches of the sky. Each such area should be wide enough to insure the elimination of minor irregularities in distribution; but a single large field would often suffice to show the characteristic grouping of the smaller telescopic stars.

The Milky Way would naturally be the first subject of inquiry; and the comparison of several plates taken in different sections of its course might be expected to yield data of great significance as regards its constitution. From simply calling over the muster-roll by orders of brightness of the stars contained in them, answers may be derived to the following questions:

(1) How far does the regular sequence of increasing numbers extend? That is, down to what grade of brightness do the stars continue nearly to quadruple with each additional magnitude?

(2) Is the progression interrupted by defect or excess, or by each alternately? In other words, does the stellar system embrace systematic vacancies as well as systematic groupings?

(3) Supposing an accumulation of stars to set in at a definite stage of space-penetration, where does it stop? Down to what magnitude is the augmented ratio of increase maintained?

(4) Are there symptoms of approaching total exhaustion of the stellar supplies beyond?

These should be found in a concurrent decrease of density with brightness, "density" being understood as the proportion of the numbers present to the space *theoretically* available for stars of a given magnitude. For one of two things seems certain: either the thinning fringe of stars is composed of really small objects interspersed among larger ones, or of average stars at average distances from us, but further and further apart from each other. In the first case the system ends abruptly; in the second, it is, as it were, shielded by outliers from the absolute void.

Particular attention should be paid to the differences of stellar distribution upon plates of the Milky Way proper, and of the dark aperture between its cloven portions. That this really forms an integral part of the galaxy is shown by the far greater profusion of small stars there than in the general sky at the outer margins of the galactic branches—a fact in itself fatal to the "spiral theory," by which the rift was interpreted as a chink of ordinary sky-background left by the interlacing, to the eye, of two great streams of stars, one indefinitely more remote than the other. From photographs we may now hope to learn what is the nature of the distinction between rift and branches—what are the magnitudes, relative numbers, and presumable mean distances, of the clustering stars present in the latter, but absent from former.

Gauges taken in the neighborhood of the southern "coal-sack" ought to prove instructive as to the nature of the nebulous stratum out of which it seems as if scooped. If the Milky Way be there shallower than elsewhere, a greater uniformity of lustre may be looked for among the stars composing it. No background profusely stored with lessening ranks will come into view, and stars below the average of those grouped in bright masses, representing their genuine companions, will be but scantily present.

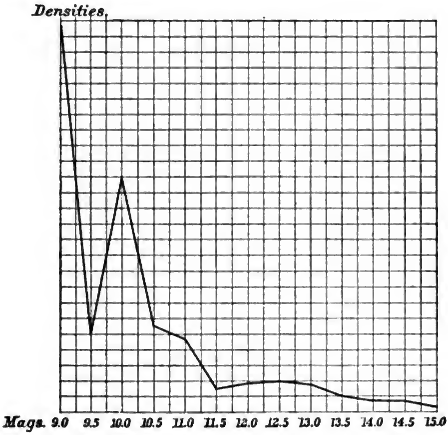
Outside the milky way, two points suggest themselves as likely to be settled by photographic gauges. Argelander found that the faintest stars in the *Durchmusterung* were everywhere in excess of their due proportion.* Even at the galactic pole, their increase, as compared with the class next below, was sextuple instead of quadruple; in the undivided galactic stream it was nine and a half, in the rift eight and a half times. If this semblance of crowding in all directions at about the mean distance of a ninth magnitude star be no accident of enumeration, then the milky way is only the enhancement of a phenomenon universally present, and the fundamental plan of the sidereal system must be regarded as that of a sphere with superficial condensation intensified in an equatorial ring. The counts, to settle this question, will have to extend over a considerable area.

The second point for photographic investigation refers to the limits of the system towards the galactic poles. There is reason to believe them comparatively restricted. M. Celoria, of the Milan observatory, using a refractor capable at the utmost of showing stars of eleventh magnitude, obtained for a "mean sounding," at the north pole of the milky way, almost identically the same number given by Herschel's great reflector.† That is to say, no additional stars were revealed by the larger instrument. Should this evidence be confirmed, the boundary of the stellar scheme should here be placed at a maximum remoteness of 3,500 years of light travel.

* *Bonner Beobachtungen*, Bd. v, "Einleitung."

† *Memorie dell' Instituto Lombardo*, t. XIV, p. 86.

As a specimen of a photographic gauge-field on a small scale, we may take Prof. Pickering's catalogue, from the Harvard plates, of 947 stars within 1° of the north celestial pole.* The region examined lies about 27° from the zone of the Milky Way, but is nearly reached by a faint extension from it. Since only one eighth magnitude star, and none brighter, are included in it, the study of distribution, for which it offers some materials, may be said to begin with the ninth magnitude. A single glance at the synoptical table suffices to show that the numerical representation of the higher magnitudes is inadequate. The small stars are overwhelmingly too few for the space they must occupy if of average brightness; and they are too few in a constantly increasing ratio. Either, then, the diminishing orders form part of a heterogeneous collection of stars of all sizes at nearly the same distance from us about




Distribution of 934 stars within 1° of the pole, showing the ratio of numbers to space for each half-magnitude.

that corresponding to ninth magnitude), or they belong to attenuated star-layers stretching to a much vaster distance. A criterion might be supplied by Prof. Holden's plan† of charting separately stars of successive magnitudes over the same area, and judging of their connection or disconnection by the agreement or disagreement in the forms of their groupings.

The accompanying diagram shows graphically the decrease of density outward, deducible from Prof. Pickering's numbers on the sole suppo-

* *Harvard Annals*, vol. XVIII, p. 138.

† Recommended in the *Century Magazine* for September, 1888, as well as in "Washburn Publications," vol. II, p. 113.

sition of the equal average luster of each class of stars. Those of the ninth are the most closely scattered. The intervals between star and star widen rapidly and continuously (for the sudden dip at 9·5 magnitude is evidently accidental) down to 11.5 magnitude, when a slight recovery, lasting to the thirteenth magnitude, sets in. How far these changes are of a systematic character can only be decided from far wider surveys.

# THE SUN'S MOTION IN SPACE.*

By Agnes M. Clerke.

Science needed two thousand years to disentangle the earth's orbital movement from the revolutions of the other planets, and the incomparably more arduous problem of distinguishing the solar share in the confused multitude of stellar displacements first presented itself as possibly tractable, little more than a century ago. In the lack as yet of a definite solution for it, there is then no ground for surprise, but much for satisfaction in the large measure of success attending the strenuous attacks of which it has so often been made the object.

Approximately correct knowledge as to the direction and velocity of the sun's translation is indispensable to a profitable study of sidereal construction; but apart from some acquaintance with the nature of sidereal construction, it is difficult, if not impossible, of attainment. One in fact pre-supposes the other. To separate a common element of motion from the heterogeneous shiftings upon the sphere of 3,000 or 4,000 stars is a task practicable only under certain conditions. To begin with, the proper motions investigated must be established with general exactitude. The errors inevitably affecting them must be such as pretty nearly, in the total upshot, to neutralize one another. For should they run mainly in one direction, the result will be falsified in a degree enormously disproportionate to their magnitude. The adoption, for instance, of a system of declinations as much as 1″ of arc astray, might displace to the extent of 10° north or south the point fixed upon as the apex of the sun's way (see L. Boss, *Astr. Jour.*, No. 213). Risks on this score, however, will become less formidable with the further advance of practical astronomy along a track definable as an asymptote to the curve of ideal perfection.

Besides this obstacle to be overcome, there is another which it will soon be possible to evade. Hitherto, inquiries into the solar movement have been hampered by the necessity for preliminary assumptions of some kind as to the relative distances of classes of stars. But all such assumptions, especially when applied to selected lists, are highly insecure; and any fabric reared upon them must be considered to stand upon treacherous ground. The spectrographic method, however, here fortunately comes into play. "Proper motions" are only angular veloci-

* From *Nature*, October 15, 1891, Vol. XLIV, pp. 572–574.

ties. They tell nothing as to the value of the perspective element they may be supposed to include, or as the real rate of going of the bodies they are attributed to, until the size of the sphere upon which they are measured has been otherwise ascertained. But the displacements of lines in stellar spectra give directly the actual velocities relative to the earth of the observed stars. The question of their distances is therefore at once eliminated. Now, the radial component of stellar motion is mixed up precisely in the same way as the tangential component with the solar movement; and since complete knowledge of it in a sufficient number of cases is rapidly becoming accessible, while knowledge of tangential velocity must for a long time remain partial or uncertain, the advantage of replacing the discussion of proper motions by that of motions in line of sight is obvious and immediate. And the admirable work carried on at Potsdam during the last three years will soon afford the means of doing so in the first, if only a preliminary, investigation of the solar translation based upon measurements of photographed stellar spectra.

The difficulties, then, caused either by inaccuracies in star catalogues or by ignorance of star distances, may be overcome; but there is a third, impossible at present to be surmounted, and not without misgiving to be passed by. All inquiries upon the subject of the advance of our system through space start with a hypothesis most unlikely to be true. The method uniformly adopted in them—and no other is available—is to treat the inherent motions of the stars (their so-called *motus peculiares*) as pursued indifferently in all directions. The steady drift extricable from them by rules founded upon the science of probabilities is presumed to be solar motion visually transferred to them in proportions varying with their remoteness in space and their situations on the sphere. If this presumption be in any degree baseless, the result of the inquiry is *pro tanto* falsified. Unless the deviations from the parallactic line of the stellar motions balance one another on the whole, their discussion may easily be as fruitless as that of observations tainted with systematic errors. It is scarcely however doubtful that law, and not chance, governs the sidereal revolutions. The point open to question is whether the workings of law may not be so exceedingly intricate as to produce a grand sum total of results which, from the geometrical side, may justifiably be regarded as casual.

The search for evidence of a general plan in the wanderings of the stars over the face of the sky has so far proved fruitless. Local concert can be traced, but no widely-diffused preference for one direction over any other makes itself definitely felt. Some regard, nevertheless, must be paid by them to the plane of the Milky Way; since it is altogether incredible that the actual construction of the heavens is without dependence upon the method of their revolutions.

The apparent anomaly vanishes upon the consideration of the profundities of space and time in which the fundamental design of the sidereal universe lies buried. Its composition out of an indefinite

number of partial systems is more than probable; but the inconceivable leisureliness with which their mutual relations develop renders the harmony of those relations inappreciable by short-lived terrestrial denizens. "Proper motions," if this be so, are of a subordinate kind; they are indexes simply to the mechanism of particular aggregations, and have no definable connection with the mechanism of the whole. No considerable error may then be involved in treating them, for purposes of calculation, as indifferently directed; and the elicited solar movement may genuinely represent the displacement of our system relative to its more immediate stellar environment. This is perhaps the utmost to be hoped for until sidereal astronomy has reached another stadium of progress, unless, indeed, effect should be given to Clerk Maxwell's suggestion for deriving the absolute longitude of the solar apex from observations of the eclipses of Jupiter's satellites (*Proc. Roy. Soc.*, vol. XXX, p. 109). But this is far from likely. In the first place, the revolutions of the Jovian system can not be predicted with anything like the required accuracy. In the second place, there is no certainty that the postulated phenomena have any real existence. If however it be safe to assume that the solar system, cutting its way through space, virtually raises an ætherial counter-current, and if it be further granted that light travels faster with than against such a current, then indeed it becomes speculatively possible, through slight alternate accelerations and retardations of eclipses taking place, respectively, ahead of and in the wake of the sun, to determine his absolute path in space as projected upon the ecliptic. That is to say, the longitude of the apex could be deduced together with the resolved part of the solar velocity; the latitude of the apex, as well as the component of velocity perpendicular to the plane of the ecliptic, remaining however unknown.

The beaten track, meanwhile, has conducted two recent inquirers to results of some interest. The chief aim of each was the detection of systematic peculiarities in the motions of stellar assemblages after the subtraction from them of their common perspective element. By varying the materials and method of analysis, Prof. Lewis Boss, director of the Albany Observatory, hopes that corresponding variations in the upshot may betray a significant character. Thus, if stars selected on different principles give notably and consistently different results, the cause of the difference may, with some show of reason, be supposed to reside in specialties of movement appertaining to the several groups. Prof. Boss broke ground in this direction by investigating 284 proper motions, few of which had been similarly employed before (*Astr. Jour.*, No. 213). They were all taken from an equatorial zone 4° 20′ in breadth, with a mean declination of +3°, observed at Albany for the catalogue of the *Astronomische Gesellschaft*, and furnished data accordingly for a virtually independent research of a somewhat distinctive kind. It was carried out to three separate conclusions. Setting aside five stars with secular movements ranging above 100″, Prof. Boss divided the

279 left available into two sets,—one of 135 stars brighter, the other of 144 stars fainter, than the eighth magnitude. The first collection gave for the goal of solar translation a point about 4° north of *α* Lyræ, in R. A. 280°, Decl. + 43°; the second, one some thirty-seven minutes of time to the west of *δ* Cygni, in R. A. 286°, Decl. + 45°. For a third and final solution, twenty-six stars moving 40″–100″ were rejected, and the remaining 253 classed in a single series. The upshot of their discussion was to shift the apex of movement to R. A. 289°, Decl. + 51°. So far as the difference from the previous pair of results is capable of interpretation, it would seem to imply a predominant set towards the northeast of the twenty-six swifter motions subsequently dismissed as prejudicial, but in truth the data employed were not accurate enough to warrant so definite an inference. The Albany proper motions, as Prof. Boss was careful to explain, depend for the most part upon the right ascensions of Bessel's and Lalande's zones, and are hence subject to large errors. Their study must be regarded as suggestive rather than decisive.

A better quality and a larger quantity of material was disposed of by the latest and perhaps the most laborious investigator of this intricate problem. M. Oscar Stumpe, of Bonn (*Astr Nach.*, Nos. 2999, 3000), took his stars, to the number of 1,054, from various quarters, if chiefly from Auwers's and Argelander's lists, critically testing, however, the movement attributed to each of not less than 16″ a century. This he fixed as the limit of secure determination, unless for stars observed with exceptional constancy and care. His discussion of them is instructive in more ways than one. Adopting Schönfeld's modification of Airy's formulæ, (the additional computative burden imposed by it notwithstanding,) he introduced into his equations a fifth unknown quantity expressive of a possible stellar drift in galactic longitude. A negative result was obtained. No symptom came to light of "rotation" in the plane of the Milky Way.

M. Stumpe's intrepid industry was further shown in his disregard of customary "scamping" subterfuges. Expedients for abbreviation vainly spread their allurements; everyone of his 2,108 equations was separately and resolutely solved. A more important innovation was his substitution of proper motion for magnitude as a criterion of remoteness. Dividing his stars on this principle into four groups, he obtained an apex for the sun's translation corresponding to each as follows:

| Group. | No. of included stars. | Proper motion. | Apex. Right ascension. | Apex. Declination. |
|---|---|---|---|---|
| | | ″ ″ | ° | ° |
| I ........................................ | 551 | 0.16 to 0.32 | 287.4 | + 42 |
| II ........................................ | 340 | 0.32 to 0.64 | 279.7 | 40.5 |
| III ........................................ | 105 | 0.64 to 1.28 | 287.9 | 32.1 |
| IV ........................................ | 58 | 1.28 and upward | 285.2 | 30.4 |

Here again we find a marked and progressive descent of the apex toward the equator with the increasing swiftness of the objects serving for its determination, leading to the suspicion that the most northerly may be the most genuine position, because the one least affected by stellar individualities of movement. By nearly all recent investigations, moreover, the solar *point de mire* has been placed considerably farther to the east and nearer to the Milky Way than seemed admissible to their predecessors; so that the constellation Lyra may now be said to have a stronger claim than Hercules to include it; and the necessity has almost disappeared for attributing to the solar orbit a high inclination to the medial galactic plane.

From both the Albany and the Bonn discussions there emerged with singular clearness a highly significant relation. The mean magnitudes of the two groups into which Prof. Boss divided his 279 stars were respectively 6.6 and 8.6, the corresponding mean proper motions 21.9″ and 20.9″. In other words, a set of stars on the whole six times brighter than another set owned a scarcely larger sum total of apparent displacement. And that this approximate equality of movement really denoted approximate equality of mean distance was made manifest by the further circumstance that the secular journey of the sun proved to subtend nearly the same angle whichever of the groups was made the standpoint for its survey. Indeed, the fainter collection actually gave the larger angle (13.73″ as against 12.39″), and so far an indication that the stars composing it were, on an average, nearer to the earth than the much brighter ones considered apart.

A result similar in character was reached by M. Stumpe. Between the mobility of his star groups, and the values derived from them for the angular movement of the sun, the conformity proved so close as materially to strengthen the inference that apparent movement measures real distance. The mean brilliancy of his classified stars seemed, on the contrary, quite independent of their mobility. Indeed, its changes tended in an opposite direction. The mean magnitude of the slowest group was 6, of the swiftest 6.5, of the intermediate pair 6.7 and 6.1. And these are not isolated facts. Comparisons of the same kind, and leading to identical conclusions, were made by Prof. Eastman at Washington in 1889. (*Phil. Soc. Wash. Bulletin*, vol. XI, p. 143; *Proceedings Amer. Association*, 1889, p. 71.)

What meaning can we attribute to them? Uncritically considered, they seem to assert two things, one reasonable, the other palpably absurd. The first—that the average angular velocity of the stars varies inversely with their distance from ourselves—few will be disposed to doubt; the second—that their average apparent luster has nothing to do with greater or less remoteness—few will be disposed to admit. But, in order to interpret truly well-ascertained if unexpected relationships, we must remember that the sensibly moving stars used to determine the solar translation are chosen from a multitude sensibly fixed,

and that the proportion of stationary to traveling stars rises rapidly with descent down the scale of magnitude. Hence a mean struck in disregard of the zeros is totally misleading, while the account is no sooner made exhaustive than its anomalous character becomes largely modified. Yet it does not wholly disappear. There is some warrant for it in nature. And its warrant may perhaps consist in a preponderance, among suns endowed with high *physical* speed, of small, or slightly luminous, over powerfully radiative bodies. Why this should be so it would be futile, even by conjecture, to attempt to explain.

# A SOUTHERN OBSERVATORY.*

By Agnes M. Clerke.

On Tuesday, August 21, 1888, the Union steamship *Mexican* crossed the line outward-bound for the cape, and a certain proportion of her passengers, amongst whom was the present writer, found themselves for the first time in the southern hemisphere. A few nights later, half an hour's darkness before moonrise gave time for a splendid display of unfamiliar stars. The Southern Cross lay prone toward the west; Alpha and Beta Centauri shone triumphantly above it; Achernar was climbing the sky on the other side of a pole singularly denuded of bright companionship; the lucid streams and knots of the Milky Way were reflected in a pearly shimmer from gently heaving waves, the brilliant effect of the entire sidereal landscape being enhanced by the presence of Jupiter and Mars close together in Scorpio, while the dim cone of the Zodiacal Light, tapering upward from the sun's place, faded out above them on the black background of the sky.

The "four stars,"

Non viste mai fuor ch' alla prima gente,

appealed to mediæval imagination as a symbol and a prophecy of the uplifting of the Cross in the waste places of the earth. Modern travellers regard them from a more prosaic point of view, and are apt to be "disappointed" at their unequal luster and slightly unsymmetrical arrangement. The firmament they help to adorn, however, is of a splendor at first sight absolutely startling, and at all times peculiarly suggestive. The dullest mind can hardly fail to be roused to wonder by the appearance of the galaxy as it extends past Sirius amidst the grand procession of the stars in Argo, or where the great rift in its structure spans the heavens from the Centaur to the Swan. The intricacy of its branches, the curdled texture of its surface, the stupendous collection of distant suns, almost palpably rounded out from the void of space in Sagittarius; the abrupt vacuity of the "Coalsack," recalling the dark "lanes" tunneling certain nebulæ and star clusters, invite, only to baffle, speculations, which the tempting analogues presented by the never-setting Magellanic Clouds, with their mixed contents of stars and nebulæ, help further to stimulate.

* From *The Contemporary Review*, March, 1889, Vol. IV, pp. 380–392.

"What is the Milky Way?" may be called the question of questions for future astronomers; but it has only of late been brought to some extent within the range of available methods. More feasible aims prompted the foundation of southern observatories. English official astronomy in particular took its rise directly from the requirements of English seamen. Flamsteed was commissioned to determine the places of the stars, not because any speculative interest attached to them, but simply in order that they might serve for divisions (as it were) of the great dial plate of the heavens, upon which the moon marked Greenwich time, and might hence be got to tell the longitude in every part of the world.

But English astronomy was incomplete, even from a strictly utilitarian point of view, so long as it failed to embrace the whole of the celestial sphere; and in proportion as England's colonial empire became consolidated, the need of a supplementary establishment to that at Greenwich was rendered more and more imperative.

In the choice of its situation, there was scarcely room for a doubt. The Cape of Good Hope was already distinguished as the scene of Lacaille's labors in 1851–'52; and these furnished the virtual starting-point of austral astronomy. As their result, 10,000 southern stars and forty-two nebulæ were known at the beginning of this century; and an indication of a somewhat anomalous character (yet the only one of any kind at hand) had been procured regarding the figure of our globe south of the equator. It seemed to show that the earth bulged the wrong way,—in other words, was prolate instead of oblate. Its correction or verification was hence of extreme interest, and the re-measurement of Lacaille's arc of the meridian came to be recognized as a prime necessity of geodetic science. By an order in council, dated October 20, 1820, the establishment of a permanent observatory at the Cape was accordingly decreed, and the first royal astronomer was immediately afterwards appointed, in the person of the Rev. Fearon Fallows, of St. Johns College, Cambridge.

A Cumbrian weaver's son, he had contrived, while still a boy working at the loom, to attain a notable proficiency in mathematics; and, his talents attracting attention, some gentlemen of the neighborhood subscribed to procure him a suitable education. He graduated in 1813, as third wrangler to Herschel's and Peacock's first and second, and was elected on the earliest opportunity a fellow of his college. The prosperity and happiness of his life culminated when he found himself as His Majesty's astronomer at the Cape, in a position to marry the eldest daughter of his first patron, the Rev. Mr. Hervey, of Bridekirk.

This however was the last fortunate event of his life. Disappointment and chagrin presided over the entire series of poor Fallows' experiences in South Africa. Suspense through circumlocutory proceedings at home, anxiety due to the misconduct or lawlessness of those employed by him in the colony, vexation indescribable at the defects

of the instrument he had chiefly relied upon, personal illness, the deaths of all the children successively born to him, at last exhausted his vital energies, and he died of dropsy supervening upon sunstroke and scarlet fever, July 25, 1831, at the age of 42. His grave is in a spot of ground consecrated by himself within a stone's throw of the broken pier of his transit instrument; and the syringa trees he planted now lean their blossom-laden branches towards the upper windows of the dwelling house where he might have hoped to spend many useful and happy years.

But his work at the Cape was not thrown away. The buildings of the new observatory were well planned and solidly executed; its site was judiciously chosen on a slightly rising ground 3 miles southeast of Cape Town, almost islanded by the converging sinuosities of the Liesbeck and the Salt River. A desolate spot enough it must indeed have been when Fallows took his first survey of it. Wolves were then still common in the neighborhood; the cries of jackals mingled at night with the metallic chirping of the Cape frogs; the last Salt River hippopotamus had, not long before, met an untimely death by drowning in its marshes; the mole-burrowed hillside was bare of almost every form of vegetation save a luxuriant crop of thistles.

Now the smiling culture everywhere apparent indicates the neighborhood of a refined English home. The slopes are in spring all abloom with lilies, asters, and gladioli, delicately striped and shaded with pink and mauve, or flaunting gaudily in purple and orange; Australian willows—the Cape substitute for laburnums—make golden patches against the dark foliage of thick-growing pines planted half a century ago by Lady Maclear on the simple plan of inserting a cone into every mole hill; clumps of aloes and eucalyptus recall the vicinity of the tropics; a grove of oaks and cypresses, due to Prof. Piazzi Smyth's skill in forestry, brings memories of England; white arums, irrepressible and all-diffusive, nestle round tree roots, strain upwards to the light through the midst of tall shrubs and hedges, fling themselves in lavish profusion amidst the lush grass, marching processionally (so to speak) or halting in dense clusters, and making milky ways of blossom along every marsh and meadow. Here indeed are lilies, enough and to spare, to strew, "with full hands," the graves of a hundred young Marcelluses.

In succession to the weaver's lad from Cockermouth, there was appointed to direct the new South African observatory a solicitor's clerk from Dundee. Thomas Henderson began, at the age of 15, to devote his leisure hours to astronomy. His instinct however was for the mathematical part of the science; and he had probably never seen a transit instrument, or handled a telescope, until after he came to reside at Edinburgh in 1819. His twofold life prospered. In his legal capacity he became secretary to Lord Advocate Jeffrey; his astronomical calculations brought him to the notice of Dr. Thomas Young, Sir John Herschel, Capt. Basil Hall, and other eminent men. In the

summer of 1829, Dr. Young gave in charge to Prof. Rigaud a memorandum urging Henderson's superior qualifications for the post of superintendent of the Nautical Almanac, vacated by his own death a fortnight later; and the recommendation was doubtless influential in procuring for him after three years the offer of the Cape observatory.

Assuming the chief command there in April, 1832, he accumulated in thirteen months, a surprising number of valuable observations, still in part unpublished. One of the results derived from them was however of so striking a character as to attract instant and universal attention. It was nothing less than the first authentic determination of the distance of a fixed star.

After Sirius and Canopus, the brightest star in the heavens is Alpha Centauri. This beautiful object is easily resolved into two,—one fully three times brighter than the other. And these two circulate round each other, or rather round their common center of gravity, in a period of about eighty-eight years. The system thus formed was discovered by Henderson to have an "annual parallax" of just one second of arc. That is to say, the apparent places of the component stars as viewed from opposite sides of the earth's orbit, differed, through a familiar effect of perspective, by $\frac{1}{162000}$ of the distance from the horizon to the zenith. The more refined determinations of Drs. Gill and Elkin, while establishing its reality, have since shown that Henderson's parallax was somewhat too large. The actual distance of Alpha Centauri from the earth is, in round numbers, 25,500,000,000 of miles. Even the ætherial vibrations of light occupy four years and four months in spanning this huge interval; yet Alpha Centauri (so far as is at present known) is the nearest neighbor of our sun in space.

The attractive power of each of these coupled stars appears to be about equal; but while one is nearly twice, the other is only half as luminous, in proportion to the amount of matter it contains, as our own sun. Hence, according to our present notions, the darker, more condensed body must be considerably more advanced on the road towards extinction than its brilliant companion, and an attentive study of its spectrum ought to give interesting results.

Henderson returned to Europe in 1833, unable, in the uncertain state of his health, to support the discomforts—long since banished with the wolves and jackals—of a residence at Observatory Hill. He became astronomer royal for Scotland in 1834, and died suddenly of heart disease ten years later.

The third astronomer at the Cape, and the first whose term of activity there was prolonged to a fitting conclusion, was an Irishman. Sir Thomas Maclear was born at Newtown Stewart, in County Tyrone, March 17, 1794. His career, like those of his predecessors, swerved insensibly towards the stars. He was a physician, practicing at Biggleswade, in Bedfordshire, whose astronomical proclivities had been fostered by the genial influence of Admiral Smyth, when summoned, as one may say, to the celestial charge of the southern hemisphere.

The royal observatories at Greenwich and the Cape of Good Hope form together an astronomical establishment such as no other nation besides our own can boast of possessing. It fitly represents the world-wide dominion of which it is the corollary. British empire on the seas led directly to British empire over the skies, the one gaining completeness as the inevitable consequence of the expansion of the other. Southern astronomy seems the proper appanage of the Anglo-Saxon race. Originating with Halley's expedition to St. Helena in 1677, Lacaille's work at the Cape formed the only exception worth mentioning to the rule of its prosecution by our fellow-countrymen on either side of the Atlantic. So far, indeed, as geometrical astronomy is concerned, it would survive, without vital injury, the destruction of all results except those obtained at Greenwich and the Cape. Geometrical astronomy is now however only one, though the most important, branch of the science.

Sir Thomas Maclear proved an indefatigable and skillful observer. He co-operated energetically with Sir John Herschel, whose memorable stay at Feldhausen, 3 miles from the Royal Observatory, coincided with the first four years of his tenure of office. He re-measured and extended Lacaille's arc, thereby not only removing all doubt as to the conformity to scientific prediction of the earth's figure, but providing an invaluable groundwork for the survey of the entire colony, now in active course of prosecution by Maj. Morris, R. E. The long list of comets observed by Maclear includes Halley's, Donati's, Biela's, Encke's at four returns, and the great "southern" one of 1843. He accumulated materials for three star catalogues, prepared for the press and published by his successors, Mr. Stone, the present Radcliffe observer, and Dr. Gill. And so completely had his interests become identified with those of his adopted home that he continued, after retiring from the observatory in 1870, to reside in its vicinity; and on his death, July 14, 1879, was laid to rest within its grounds. His son, Mr. George Maclear, retains charge of the transit circle procured by his father in 1855. It is an exact copy of that erected by Sir George Airy at Greenwich.

Mr. Stone was chief assistant at Greenwich when induced to accept the appointment to the Cape by the opportunity it offered for the preparation of an extensive star catalogue, by the comparison of which with the earlier Madras and Brisbane catalogues something might be learned about the movements of southern stars. This object was most satisfactorily attained by the publication of the "Cape Catalogue for 1880," containing nearly 12,500 accurately determined star-places. By a pure coincidence, Dr. Gould's simultaneous work at Cordoba had the same scope. Its brilliant results are familiar to all astronomers.

Mr. Stone surrendered the direction of the observatory, in June, 1879, to the present royal astronomer. Dr. Gill is one of a long line of distinguished Aberdonians. An astronomer by "irresistible impulse," he,

like Bessel, exchanged lucrative mercantile pursuits for the comparatively scanty emoluments awaiting the votaries of the stars. The "patines of bright gold," with which Urania's treasure chests overflow, are not of terrestial coinage.

The distance of the sun was the first problem upon which Dr. Gill delivered a substantial attack; and his solution of it still remains the best obtained by celestial trigonometry, corresponding so closely with Newcomb's value of the same great unit, derived from direct measurement of the velocity of light, as to reduce within reassuringly narrow limits the uncomfortable margin of uncertainty left by the transits of Venus. In the observations of Mars made for this purpose at Ascension in 1877,* Dr. Gill employed the instrument of his predilection, called—on the *lucus à non lucendo* principle—a "heliometer."

A heliometer is a telescope of which the object glass has been sawn in two. This does not sound like, nor would it be, an improvement for purposes of simple star-gazing; but the end in view is different. It is that of precisely determining the angular distances between adjacent stars, or between a planet and stars near it, though in many cases beyond the range of the ordinary micrometer. The following is the way in which this end is compassed.

The half lenses of the object glass are separable by a very fine screw motion, and they form independent and separable images of any object upon which the telescope is pointed. These images unite into one when the two segments unite to complete one circle; as they are made to slide apart, the images to slip sideways asunder, to an extent which can be measured with the minutest accuracy by exquisitely divided scales read with a powerful microscope. In the actual process of observation, the telescope is fixed upon a point midway between the stars under scrutiny, so that the field of view is, to begin with, empty. Neither star can-be seen. Then the segments of the object glass are moved oppositely along a line brought beforehand to agree with the line of direction between the stars, until the more westerly (say) of the pair as imaged by one segment, and the more easterly as imaged by the other, begin simultaneously to appear, and are at last carefully made to coincide in the middle of the field. After the scales have been read, the motion is reversed, and a similar coincidence is brought about between the oppositely corresponding stars—that is, between the easterly member of the pair shown by segment No. 1, and the westerly member of the pair shown by segment No. 2. The total distance traversed is, of course, equal to twice the distance between the stars.

The refinements, however (which can not here be explained), attendant upon these operations are what make their results valuable, and the process of educing them laborious. With the Copernican "triquetrum" the measured apparent intervals between any two of the

* For a popular account of the expedition, see Mrs. Gill's charming "Six Months in Ascension." Murray. Second edition. 1880.

heavenly bodies could be depended upon to within ten minutes; with the new Repsold heliometer the error of a single observation is less than one-tenth of a second of arc. So that accuracy has been increased, in the course of three and a half centuries, some six thousand times. At what cost of patience and expenditure of the counted moments of individual human lives, as the fruit of what illuminations of genius, throes of invention, failures, and disappointments in some quarters, compensatory triumphs in others, can never rightly be told. The progress achieved was by "leaps and bounds;" it must henceforth be by slow and painful foot lengths, as the limit of possible accuracy is brought imperceptibly nearer. It is not likely that the astronomical data of three and a half centuries hence will be six thousand times more accurate than those at our disposal.

The heliometer is, of all others, the instrument best adapted for the work (exceedingly simple in principle, yet delicate to an almost inconceivable degree in the details of its execution) of determining stellar parallaxes. The diameter of the earth's orbit affords a base line 186,000 miles in length, from opposite extremities of which—that is, at opposite seasons of the year—the distances between the object to be examined and two "comparison stars" are measured. The infinitesimal alternate shift of the star nearest the earth to and from those with which it is compared (assumed with little risk of error, to be indefinitely remote) is called its "parallax." From its angular amount the distance in miles of the star from the earth can be at once derived.

The minuteness of this little parallactic see-saw is difficult to be realized by those unpracticed in such matters. A displacement of one second on the sphere is equivalent to a shifting across the width of a human hair placed 70 feet from the eye. But no known star has so large a parallax as one second, which is as much as to say that no known star is so near to us as 200,000 times the distance of the sun. Positive results might, under these circumstances, well have been despaired of; yet they have, in a number of cases, been attained, and form the surest groundwork so far provided for investigations into the mechanism of the skies.

Dr. Gill's observations for stellar parallax were begun at the Cape July 5, 1881, with the Dunecht heliometer, of which he had become the possessor by private purchase from the Earl of Crawford. He had as a coadjutor Dr. W. L. Elkin, who is now in very effective charge, at Yale College, of the only heliometer yet erected on any part of the American continent. Nine stars in all were measured, of which two gave no indications of possessing any sensible parallax. Both, remarkably enough, are brilliant stars of the first magnitude—Canopus and Beta Centauri—which, to shine as they do, from unfathomable depths of space, must be objects of astounding splendor. Canopus, especially, can not emit less, and may emit a great deal more, than fifteen hundred times the light of our sun, unless, indeed, Dr. Elkin's "comparison stars" should turn

out to be physically connected, consequently, at nearly the same distance from ourselves with the giant luminary they attend. This doubt will shortly be set at rest by Dr. Gill's measures, now being carried out with a different pair of stars.

Sirius was shown by the observations of 1881–'83 to be at a distance such that its light occupies nearly nine years in reaching us. Its real brightness is that of sixty-three suns, while it attracts the semi-obscure body circulating round it in forty-nine years, with no more than thrice the solar power. This extraordinary luster relative to mass seems to belong to all stars of the Sirian pattern as to spectrum, and is due most likely in part to their elevated temperatures, in part to the scantiness of their vaporous surroundings.

The success of the Cape investigations in this difficult branch of astronomy invited their continuation on a larger scale, and with more powerful instrumental means. The Government was accordingly induced to sanction the construction, by Messrs. Repsold of Hamburg, of a new heliometer of above 7 inches aperture, mounted last year in a building erected for its reception on the summit of the sunny slopes of Observatory Hill. The first view of this great star-measuring machine has, it must be admitted, a somewhat bewildering effect upon the uninitiated onlooker. The eye end literally bristles with steel rods, handles, and screw-heads, almost as numerous as the stops of an organ, and requiring no less skill and knowledge for their proper use. The revolving "head" is armed with a strange-looking, radiated head-gear, like the sails of a windmill, or a nimbus of tin sectors surviving from a barbarous age.

Everything here has however a definite purpose. These surprising "flappers" are, in fact, screens of wire gauze of graduated closeness, used for equalizing the brightness of the stars in the field of view, and so enabling the eye to hold the balance, as it were, even between them. The complex apparatus close to the observer's hand furnishes him with the means of easy control over the whole of the sky-gauging mechanism provided for him. None more perfect has been devised, yet the study of its "errors" is the indispensable preliminary to its use.

Only the sublime end in view could render tolerable the process of arriving at a complete "theory" of such an instrument. The patient laboriousness so readily commended in the heroes of science costs more than the readers of their biographies are apt to imagine. Interminable readings of scale divisions, interminable castings-up of the columns of decimals expressing the differences of the successive readings, are not in themselves exciting occupations. But they must be pursued during some hours a day for a whole year before the "division errors" of the new heliometer can be regarded as completely abolished because perfectly known. Nor is this all. Elaborate corrections and interpretations of other kinds have to be added, to say nothing of endless and anxious precautions in the observations themselves—precautions against personal and physiological, as well as against atmospheric and

instrumental, causes of error. Accuracy is indeed arduous; and the astronomer who is not what the old Romans used, in their grand way, to look down upon as a *cumini sector*, had better learn another profession.

Twenty-seven stars in the southern hemisphere are now being, or are about to be, measured for parallax with the Cape heliometer. Their selection was governed by the ultimate object of gathering information as to the scale and plan of the marvellous aggregation of suns to which our sun belongs, and amidst which it is moving, in an unknown orbit, to meet unknown destinies. For this purpose, facts of two kinds are urgently needed—facts relative to the real distribution, and facts relative to the real movements of the stars in space. Dr. Gill's operations, when completed, can not fail to bring important reinforcements to our present small store of each.

Ten stars of the first magnitude lie to the south of the celestial equator, of which nine (Alpha Centauri being already safely disposed of) are in course of measurement at intervals of six months. The upshot will be to give the average distance corresponding to the first order of stellar brightness in the southern hemisphere. An analogous result has lately been published by Dr. Elkin for the ten chief northern luminaries. Their distance, "all round," proves to be thirty-six "light-years." That is to say, light from their photospheres affects our senses only after our planet has revolved, on an average, thirty-six times in its orbit round the sun. So that all our knowledge, even of the stars presumably nearest to the earth, refers, in this year 1889, to the "mean epoch" 1853. We shall learn presently whether the "mean epoch" for the southern bright stars corresponds approximately to this date, or whether a marked disparity may countenance the surmise of our eccentric situation in the group of luminaries to which our sun more especially belongs.

Dr. Gill's list includes five second magnitude stars, the annual perspective displacements of which (if large enough to be measurable) will give something like a definite scale of increasing distance with decreasing luster. A conclusion will then be feasible as to the rate of movement of the sun in space. The elder Struve made it about 5 miles a second, but on the supposition of the brightest stars being between two and three times nearer to us than they seem really to be. We can now see that the actual speed of the solar system can scarcely fall short of 12, or exceed 20 miles, a second. By a moderate estimate, then, our position in space is changing to the extent of 500,000,000 of miles annually, and a collision between our sun and the nearest fixed star would be inevitable (were our course directed in a straight line toward it) after the lapse of fifty thousand years!

The old problem of "how the heavens move," successfully attacked in the solar system, has retreated to a stronghold among the stars, from which it will be difficult to dislodge it. In the stupendous mechanism of the sidereal universe, the acting forces can only betray themselves to

us by the varying time configurations of its parts. But as yet our knowledge of stellar movements is miserably scanty. They are apparently so minute as to become perceptible, in general, only through observations of great precision extending over a number of years. Even the quickest-moving star would spend two hundred and fifty-seven years in crossing an arc of the heavens equal to the disc of the full moon. Yet all the time (owing to the inconceivable distances of the objects in motion) these almost evanescent displacements represent velocities in many cases so enormous as to baffle every attempt to account for them. "Runaway stars" are no longer of extreme rarity. One in the Great Bear, known as "Groombridge, 1830," invisible to the naked eye, but sweeping over at least 200 miles each second, long led the van of stellar speed. Prof. Pritchard's photograpic determination of the parallax of $\mu$ Cassiopeiæ shows, however, that inconspicuous object not only to be a sun about forty times as luminous as our own, but to be traveling at the prodigious rate of 300 miles (while Dr. Elkin's result for Arcturus gives it a velocity of little less than 400 miles) a second!

The "express" star of the southern hemisphere, so far, is one of the fourth magnitude situated in Toucan. Its speed of about 200 miles a second may however soon turn out to be surpassed by some of the rapidly-moving stars picked out for measurement at the Cape. Among them are some pairs "drifting" together, and presumed therefore to be connected by a special physical bond, and to lie at nearly the same distance from ourselves. This presumption will now be brought to the test.

A remarkable and typical change has affected the aims pursued at our southern national observatory since Dr. Gill assumed its direction. There has been a widening of purpose matching the widened scope of astronomical science due to the development of new methods. The practical usefulness of the establishment was never more conspicuous than at present. The shipping interests, railway service, and surveying operations of South Africa are in immediate dependence upon it. The whole fabric of the "old astronomy"—so far as one hemisphere is concerned—is held together by the re-determinations of "fundamental" and "standard" stars continually in progress at it. But while nothing of what was previously held in view has been relinquished, much of incalculable value has been added. Above all, the ideal, or purely intellectual, side of astronomy has obtained recognition, and in a form likely to be memorable in the history of the science.

The celestial-photographic Paris Congress of April, 1887, might be called "epoch making," for this reason alone—that it marked, officially and forever, investigations into the structure of the sidereal universe as part of the proper duty of astronomers. These inquiries, the most sublime of the physical kind with which the mind of man can be occupied, will not henceforth be abandoned to individual caprice, to be prosecuted by necessarily inadequate means, and neglected when those means (as they could not fail to do) should collapse under the strain

put upon them. They will be pursued gravely, systematically, by the concerted efforts of successive generations, through the toil of innumerable unpretending workers guided to effectiveness by the highest intelligence of the times. A measure of success is, under these circumstances, certain, and even a small measure of success in this direction will suffice to broaden and deepen the channels of all future human thought.

Hence the profound significance of the decisions of the Paris Congress, by which an international scheme for photographically charting the heavens and cataloguing a large proportion of their contents was set on foot. Fortunately for its own reputation our Government, after long delay, has adopted what might have seemed the foregone conclusion that a share in this work is England's right and duty, and has authorized the construction of the requisite instruments for Greenwich and the Cape. Before another year has elapsed they will be mounted in their respective places and the recording process, to be carried on simultaneously at fourteen or fifteen observatories in every part of the world, will have begun.

Meanwhile Dr. Gill, to whose initiatory energy the approaching realization of this great plan is due, has almost completed a preliminary task of vital importance to its due accomplishment, as well as to sidereal science in general. One of the most famous achievements of recent astronomy is the "*Bonn Durchmusterung*," a list of 324,000 stars from the North Pole to 2 degrees south of the equator, observed by Argelander at Bonn. Until it was compiled the smaller stars were a nameless crowd with no recognized identity. For the purposes of science they could scarcely be said to exist. But once

Set in note-book, learned and conned by rote,

their changes could no longer elude notice; and detected change leads commonly to increased knowledge. A solid foundation was moreover laid for the study of sidereal statistics, destined, perhaps, to lead to momentous results at no distant future.

An extension of the "*Durchmusterung*" to the southern hemisphere was contemplated from the first, but was more easy to contemplate than to execute. No southern observatory was in a condition to undertake a task so colossal. Dr. Schönfeld, Argelander's successor at Bonn, carried, however, the enumeration as far as the southern tropic, where it seemed likely to stop, when some surprising photographs of the great comet of 1882, projected on wide fields of stars, taken at the Royal Observatory with the help of Mr. Allis, of Mowbray, opened to Dr. Gill the possibility of completing Argelander's stellar review by this relatively unlaborious method. And the possibility is rapidly being converted into an accomplished fact. Two assistants, Mr. C. Ray Woods and Mr. Sawerthal, are employed every fine night in exposing plates with instruments, each consisting virtually of two telescopes, one for concentrating upon the plates the rays of the multitudinous stars within a field of 36 square degrees, the other for enabling the

operator to keep them steadily there until their self-portraiture is finished. The whole heavens, south of the tropic of Capricorn, will have been covered in duplicate by next April, after which only some supplementary exposures will remain to be made.

Prof. Kapteyn, of Leyden, is meanwhile busy measuring the plates successively transmitted to him from the Cape, and the resulting catalogue—the first derived from photographs—will probably be in the hands of astronomers by the year 1892. All stars down to the ninth magnitude, and many fainter, will be included in it to the number of fully two hundred thousand. This important enterprise is a private and personal one. The entire responsibility for it, financial and other, is borne by Dr. Gill.

There is a prospect that before another year has elapsed, the vexed question of the sun's distance will have been definitely set at rest. The immediate objects of measurement for the purpose with the Cape heliometer, in combination with some other instruments of the same class in Germany and America, are three of the minor planets—Iris, in October and November, 1888; Sappho and Victoria during the summer of 1889. The position of the planet between successive pairs of stars distributed along its path during the favorable period when it culminates near midnight will be determined simultaneously from opposite sides of the equator according to a method devised by Dr. Gill, so stringent and insistent for accuracy that the errors admitted by it must be minute indeed. While celestial surveyors have 270 asteroids at their disposal to mark the apexes of their triangles, the long gaps of time between the transits of Venus need be of little concern to them.

To describe the whole of the tasks in progress at the Royal Observatory—the cometary work chiefly in the hands of Mr. Finlay, the first assistant, the lunar, and planetary observations, the laborious corrections of star places and star motions—would demand more space than is at our command. What has here been aimed at is merely to indicate the directions in which the activity of the establishment tends to expand, and to show that these directions are representative of the present, and must be decisive as to the future of astronomy. There is room indeed, were the material means at hand, for further expansion. In the spectroscopic department the Cape record is still a blank. Yet the wise outlay of a few hundred pounds would suffice to set on foot, under exceptionally favorable circumstances as to climate and situation, inquiries into the physical condition of southern stars of extreme interest and inevitable necessity.

There is much to be learned, as well as enjoyed, from a visit to the Cape Observatory. Not only the work done there, but the manner in which it is done, is impressive. Lessons of earnestness of purpose, stability of aim, and cheerful self-devotion can scarcely be missed by the itinerant lover of astronomy, in whose mind they will be tempered and illuminated by reminiscences of the beauty of flowers by day and of the glory of stars at night.

# SOME APPLICATIONS OF PHYSICS AND MATHEMATICS TO GEOLOGY.*

By C. Charles CHREE, M. A.

## I.—SOME PHYSICAL AND MATHEMATICAL DATA.

Many of the terms employed in treating of the properties and conditions of matter have in common use a somewhat vague meaning. The meaning, so far as clearly outlined, is also only too often different from that which the physicist intends to convey. As regards terms such as rigid, solid, plastic, viscous, etc., it seems to me that even eminent geologists are apt to be misled by the popular usage, so that they fall into error respecting the data which mathematical and physical science places at their disposal. It thus seems advisable on the present occasion to clear the ground by briefly considering the sense attached to these terms by the more exact school of physicists. To render the following statements intelligible it is necessary to explain the meaning scientifically attached to the terms stress and strain. By stress is meant a force referred to unit of area of the surface across which it acts; by strain the increase in the distance between two material points divided by the original distance. For instance, if a vertical bar $n$ square inches in cross section fixed at the upper end, sustain a load of $t$ tons, and the load be uniformly distributed over the cross section, the longitudinal stress is $tn$, taking the square inch as unit of area and the weight of 1 ton as unit of force. If a portion of the bar increase in length from 100 to 100.01 inches, and the increase be uniformly distributed over the portion lengthened, the longitudinal strain is $(100.01-100)\times 10^{-2}$, or .0001.

The writers who have had most influence on the present scientific usage of English terms dealing with physical properties are unquestionably Prof. Clerk Maxwell and Sir William Thomson. The former gives the following definitions in his Theory of Heat †: "A body which when subjected to a stress experiences no strain would, if it existed, be called a perfectly rigid body. There are no such bodies. - - -"

* From the *L. E. D. Phil. Mag.*, September and October, 1891; vol. XXXII, pp. 233-252, and 342-353.

† Fifth edition, chapter XXI.

"A body which when subjected to a given stress at a given temperature experiences a strain of definite amount, which does not increase when the stress is prolonged, and which disappears completely when the stress is removed, is called a perfectly elastic body."

"If the form of the body is found to be permanently altered when the stress exceeds a certain value, the body is said to be soft or plastic, and the state of the body when alteration is just going to take place is called the limit of perfect elasticity."

"If the stress, when it is maintained constant, causes a strain - - - which increases continually with the time, the substance is said to be viscous."

A viscous material may be either solid or fluid. It is regarded by Maxwell as fluid when any stress, however small, produces a constantly increasing strain. Maxwell draws a distinction between elasticity of bulk and elasticity of shape—the latter being peculiar to solids—which is more fully treated of by Sir William Thomson. A body possesses perfect elasticity of bulk when on the removal of the stress it returns to its original volume, even though the form of its surface be permanently altered. Both writers regard it as certain that solid bodies will retain perfect elasticity of bulk under compressive stresses which far exceed the limit of elasticity of shape. The following statement embodies the views of Sir W. Thomson*: "If we reckon by the amount of pressure, there is probably no limit to the elasticity of bulk in the direction of the increase of pressure for any solid or fluid; but whether continued augmentation produces continued diminution of bulk toward zero without limit, or whether for any or every solid or fluid there is a limit toward which it may be reduced in bulk, but smaller than which no degree of pressure, however great, can condense it, is a question which can not be answered in the present state of science."

Maxwell, by denying the existence of a perfectly rigid body, maintains that every solid can sustain stress or transmit force only by suffering strain. Thus, on depositing a feather on the most solid block of iron we produce in the iron a system of strains, infinitesimally small it is true, but whose existence can no more be questioned than the existence across the surface separating the iron and the feather of forces balancing the portion of the feather's weight left uncompensated by the air pressure. The hypothesis quoted above from Sir W. Thomson, that there may be a limit beyond which no body can be compressed, is not inconsistent with Maxwell's statement. The hypothesis regards the ratio of the increment of strain to the increment of pressure as ultimately becoming infinitesimally small, but it in no way implies that this ratio ever becomes absolutely zero.

In a solid bar, supposed perfectly elastic, exposed to longitudinal stress, the ratio of the stress to the strain is styled Young's modulus. In many materials Young's modulus varies in magnitude according to the

* *Mathematical and Physical Papers*, vol. III, pp. 7–8.

direction in which the axis of the bar is taken. Thus, in ordinary woods there is a marked difference between the value of Young's modulus in the direction of the pith of the tree and in any perpendicular direction. Materials in which Young's modulus is independent of the direction in which the axis of the experimental bar is taken are termed isotropic; all others are termed æolotropic.

In an isotropic elastic solid it is supposed, on the ordinary British or biconstant theory, that the value of Young's modulus, E, alone is insufficient to define the elastic structure, and that some other elastic constant must be known. For many purposes the most convenient additional constant is the ratio of the lateral contraction to the longitudinal extension—each measured per unit of length—in a bar exposed to simple longitudinal traction. For instance, if the diameter of a bar under uniform longitudinal stress change from 10 to 9·9997 inches the lateral contraction is 0·00003, and if the longitudinal strain be 0·0001, the ratio of lateral contraction to longitudinal extension is 0·3. This ratio is termed Poisson's ratio, and is represented here by $\eta$.

On the uniconstant theory of isotropy $\eta$ must have the value 0·25, which certainly accords well with experiments on glass and some of the more common metals, especially iron and steel under certain conditions.

On the biconstant theory $\eta$ may have any value within certain limits. The existence of these limits, it must be admitted, is seldom recognized, and experimental results are not infrequently referred to which are inconsistent with the view taken here, viz, that $\eta$ must lie between 0 and 0.5. If, however, $\eta$ were negative in any material a circular bar of this material, when subjected to uniform longitudinal tension, would increase in diameter; while if $\eta$ were greater than 0.5, the bar, when fixed at one end and subjected to a torsional couple at the other, would twist in the opposite direction to the applied force. Until these phenomena are shown to present themselves in isotropic materials—and the experimental verification ought to be easy—it seems legitimate to suppose that when experimentalists deduce values for $\eta$ which lie outside of these limits, their experiments refer to bodies whose constitution is different from what is assumed in their mathematical calculations.

The properties attributed to an isotropic elastic solid by the ordinary mathematical theory are as follows:

(A) The strain must be elastic, *i. e.*, it must disappear on the removal of the stress.

(B) The ratio of stress to strain must be independent of the magnitude of the stress, or, in Prof. Pearson's words, the stress-strain relation must be linear.

(C) The strains must be small.

(D) The values of Young's modulus and Poisson's ratio in a bar of the material must be independent of the direction in which the axis of the bar is taken.

The last property alone distinguishes isotropic from aeolotropic elastic solids.

(A) answers to Maxwell's definition, but (B) and (C) are not assumed by Maxwell. In other words, a solid may be perfectly elastic without showing a linear stress-strain relation, or possibly even after the strains have become large. Thus, for the sake of clearness, I shall call Maxwell's limit of perfect elasticity the physical limit, and the limits supplied by (B) and (C) the first and second mathematical limits respectively.

It is not infrequently taken for granted that the physical and the first mathematical limit are necessarily identical, *i. e.*, that the elasticity is certainly not perfect when the stress-strain relation ceases to be linear. According however to some experimentalists cast iron is as perfectly elastic as any other metal in the sense of Maxwell's definition, but the stress-strain relation for even small strains is sensibly not linear.* This is, of course, a question for experimentalists to decide, but in any case where their final verdict is, that the stress-strain relation is sensibly not linear, the employment of the ordinary mathematical theory is unjustifiable. It must be admitted that the principle (C) is a very vague one, leading to no exact limit, and that it seldom receives any very formal acknowledgment. It is, however, clearly recognized, and a reason for it assigned in the following statement, due to Thomson and Tait:† "The mathematical theory of elastic solids imposes no restrictions on the magnitudes of the stresses except in so far as that *mathematical necessity requires the strains to be small enough to admit of the principle of super-position.*" The italics are mine. The meaning is that the strains must be small fractions whose squares are negligible compared to themselves. If this principle be neglected and the mathematical equations be supposed to apply when the strains are large, the difficulty of giving them a consistent physical interpretation is very great if not wholly unsurmountable.

In most materials having any claim to be regarded as elastic solids the stress-strain relation for most ordinary stress systems certainly ceases to be linear while the strains are still small. We shall thus in the meantime leave the condition (C) out of account, though we shall have to return to it in treating of the so-called "theories of rupture."

The existence of the properties (A), (B), (D), presupposed by the mathematical theory, is determined not solely by the chemical constitution of the body, but also by the treatment to which it has been subjected. Thus a freshly annealed copper wire may, when loaded for the first time, be far from satisfying conditions (A) or (B), and yet by the process of loading and unloading it may be brought into a state of ease, wherein these two conditions are very approximately, if not exactly

* See Todhunter and Pearson's *History of Elasticity*, vol. I, art. [1411] and pp. 891–893.

† *Nat. Phil.*, vol. I, part II, p. 422.

fulfilled, so long as the stress does no exceed a certain limit. Again, the fact that a large mass of metal is sensibly isotropic is no sufficient reason for attributing isotrophy to the same metal when rolled into thin plates or drawn into thin wires.

It is quite possible that the three conditions (A), )B), and (D) represent an ideal state which is never actually reached, and that a divergence may always be shown by the use of very delicate apparatus. If this be true, then the results obtained by the mathematical theory can not claim absolute correctness. It seems however to be satisfactorily established that many materials in the state of ease satisfy these conditions with at least a very close approach to exactness, so that the results of the mathematical theory when properly restricted are then sufficiently exact for practical purposes.

From the preceding statements it will be seen that it is of the utmost importance to know what are the limits within which the conditions assumed by the mathematical theory are satisfied with sufficient exactness to justify its application. This question must of course be settled by experiment, but it is beset by various difficulties which ought to be clearly recognized. These arise in part from the serions obstacles in the way of a complete experimental knowledge, and in part from the want of a proper understanding between those interested in the practical and theoretical sides of the subject, and a consequent confusion in the terms used.

To avoid complication let us begin by supposing the mathematical limit of perfect elasticity to coincide with the physical. Let us consider the simple case of a bar under uniform longitudinal traction. We may suppose the bar isotropic, and in consequence of suitable treatment perfectly elastic for loads not exceeding $L_1$. No mechanical treatment, we shall suppose, can render it perfectly elastic for loads greater than $L_2$. It does not follow that a load $L_2$ will necessarily rupture the bar either immediately or in course of time, but simply that for any load greater than $L_2$ the strain is not perfectly elastic. Increasing the load from zero we should reach a load $L_3$, probably greater than $L_2$, that would in process of time rupture the bar, or a load $L_4$ greater than $L_3$ that produces immediate rupture. All these loads are supposed to refer to unit of area.

Now in the initial state of the bar we should be entitled to apply the mathematical theory only until the load $L_1$ was reached. When we aim at finding the utmost capability of the material under longitudinal load, we may perhaps apply the theory until the load $L_2$ is reached, but here we must stop. To apply it until the loads $L_3$ or $L_4$ are reached—assuming these greater than $L_2$—is clearly inadmissible.

Results of a similar kind hold for all the comparatively simple forms of stress—such as pure compression, torsion, or bending—in which practical men are interested. There are limits to the state of perfect elasticity lower than the limits at which rupture takes place, at least immediately.

The usual aim of the engineer is that no part of the structure he is designing should ever be strained beyond the elastic limit, and this end he of course desires to obtain with the least possible expenditure of material. Thus ideally he might be expected to calculate the dimensions of each piece, so that for the maximum load it is to be subjected to it shall just not pass beyond the limit of perfect elasticity. There are however in general agencies, such as wind pressure, dynamical action of a moving load, etc., whose effects are not very fully understood and whose magnitude can not always be foreseen. Thus it is the custom to allow a wide margin for contingencies. Now the limit of perfect elasticity seems the natural quantity to employ in allowing for this margin, but the uncertainties attending its determination are such that it is customary to employ the breaking load instead. The breaking load for the particular kind of stress the member in question is to be exposed to is divided by some number, *e. g.*, 4 or 5, called a *factor of safety*, and the dimensions of the member are calculated so that its estimated load shall not exceed the quotient of the breaking load by the factor of safety. The engineer varies the factor of safety according to the nature of the load, and according to the confidence he possesses in the uniformity of the material and in the completeness of his knowledge as to the vicissitudes the structure is exposed to. It has thus come to pass that attention has been largely directed to the breaking loads, and theories have been constructed which aim professedly at supplying a law for the *tendency to rupture*, under the most general stress systems possible, of materials whose rupture points have been found under the ordinary simple stress systems employed in experiment.

There are only two such theories of rupture for isotropic materials that at present possess any general repute. To understand them the reader requires to know that for any stress system there are at every point in an isotropic elastic material three principal stresses along three mutually orthogonal directions, and likewise three principal strains whose directions coincide with those of the principal stresses. If an imaginary small cube of the material be taken at the point considered with its faces perpendicular respectively to the three principal stresses, then no tangential stresses act over these faces. In a bar under a uniformly distributed longitudinal stress L per unit ot cross section, two of the principal stresses are everywhere zero, and the third is parallel to the axis and equals L. If E be Young's modulus, and $\eta$ Poisson's ratio for the material, supposed isotropic and elastic, the greatest principal strain is everywhere $L/E$ and its direction is parallel to the axis. The two remaining principal strains are each $-\eta L/E$ and they may be supposed to have for their directions any two mutually perpendicular lines in the cross section of the bar.

One of the theories referred to above is, that when the algebraic difference between the greatest and least of the principal stresses at any

point—a pressure being reckoned negative—attains a certain value, rupture will ensue at this point. Thus, if in descending order of magnitude, the principal stresses at a point be $T_1$, $T_2$, $T_3$, then $T_1—T_3$ is the stress difference* at this point, and the theory asserts that rupture will ultimately ensue if the stress difference anywhere equals $L_3$, the load for ultimate rupture of a bar of the material by longitudinal traction; while if the stress difference anywhere equals $L_4$, the load for immediate rupture by longitudinal traction, then immediate rupture will ensue.

The second theory, which is supported by the great authority of de Saint-Venant,† replaces the stress difference of the first theory by the greatest strain. It thus asserts that the condition for rupture is found by equating the largest value found anywhere for the greatest strain to the longitudinal strain answering to longitudinal traction $L_3$, or to that answering to the traction $L_4$, according as the rupture is ultimate or immediate. This theory maintains that extension in some direction is necessary for rupture.

The two theories may, as in the case of pure longitudinal traction, lead to the same result; but in general they do not, so one at least of them must be wrong. When we examine the theories, still supposing the mathematical and physical limits of perfect elasticity the same, a very obvious difficulty‡ presents itself. It is assumed that the stress-difference and greatest strain are derived by the mathematical theory; but that theory applies only so long as the material is everywhere perfectly elastic, whereas rupture, at least when immediate, presents itself after the elastic limit has been passed. Thus if the application of the mathematical theory leads to values for the maximum stress difference and greatest strain equal to the values of these quantities answering to rupture, at all events when immediate, the true conclusion would seem to be that the fundamental hypothesis on which the treatment proceeds, viz, that the material follows the laws assumed by the mathematical theory, has been shown to be incorrect. Nothing has been proved except that the elastic limit must be passed and that the mathematical theory does not apply.

The only logical way of interpreting the theories is to suppose that the maximum stress difference and greatest strain are to be compared not with the values that answer to rupture, but either with those that answer to the limit of perfect elasticity or with those derived by dividing the values answering to rupture by some factor of safety. This factor must then be large enough to prevent the limit of perfect elasticity being passed. Thus from either point of view we encounter a formidable difficulty, viz, the uncertainty of what is the limit of perfect elasticity.

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* See Prof. Darwin, *Phil. Trans.*, 1882, pp. 220, 221, etc.; also Thomson and Tait's *Nat. Phil.*, vol. I, part II, p. 423.

† See Pearson's *The Elastical Researches of Barré de Saint-Venant*, art. 5 (c), etc.

‡ *Ibid.* art. 4 (γ), 5 (a), &c.

We have supposed that a bar may be brought into a state in which it is perfectly elastic for longitudinal tractions not exceeding $L_2$. Answering to this we have $L_2$ for the stress difference, and $L_2/E$ for the greatest strain. Now if the two theories described above really apply to the limit of perfect elasticity, the one would seem to maintain that $L_2$ is the limiting value of the stress difference, the other that $L_2/E$ is the limiting value of the greatest strain for all possible stress systems in material of the same kind as that in the bar. The complete experimental proof or disproof of such theories is not likely to be easy. Thus taking for instance the case of longitudinal traction, suppose it were shown that a certain method of treatment which raises the elastic limit for load parallel to the axis of a bar does not raise the elastic limit for longitudinal load in a bar whose length lay in the cross section of the original bar. This would only suffice to prove that the treatment adopted did not give a fixed elastic limit the same for all kinds of strain, it would leave the possibility of such a limit being obtained in some other way an open question.

In the preceding remarks the mathematical and physical limits of perfect elasticity have been supposed identical. When they differ, the mathematical limit is of course that which must be employed in determining the range of the mathematical theory. It will certainly not exceed the physical limit. I may add that while for certain structures such as isolated boilers the physical limit may most nearly concern the practical engineer, in other structures, such as girder bridges, the stress-strain relation is assumed to be linear in designing the several parts, so that the first mathematical limit is then of the utmost practical importance.

In the previous discussion of the stress-difference and greatest-strain theories, as settling the limits of application of the mathematical theory, it has been taken for granted that the condition (C) was safeguarded by them. Now in most ordinary systems of loading this is probably the case, but it is not always so. For instance, if we assume the mathematical theory to hold, a solid isotropic sphere under a uniform surface-pressure shows none but negative strains, and the three principal stresses are everywhere equal. Thus the greatest strain is everywhere negative, and the stress difference everywhere zero. This is true irrespective of the magnitude of the surface pressure, and so, according to both theories, the stress-strain relation would be linear and the mathematical theory would apply, however large the pressure was. According to the theories, one might continue to employ mathematical formulæ which indicated a reduction of the sphere to one-millionth of its original volume. It is obvious, however, that a reduction of the volume by even a tenth would produce strains which are probably far in excess of those admitted by the principle (C). In formulating an objection to the universal application of the theories, I have preferred to attack them on the side of the principle (C) so as to

show clearly that the high authority of Thomson and Tait is on my side. The example considered raises however what seems to me at least an equally strong argument against the theories from the side of the principle (B). For we must remember that the stresses inside the material are determined by the intermolecular forces. Now whatever molecules may be, and however they may act on one another, it seems incredible that the molecular forces should lead to one and the same stress-strain relation, however much the mean molecular distance may be reduced. The fact that Sir W. Thomson regards the existence of an irreducible minimum volume as possible may, I think, be taken as proof that he is opposed to the view that it is possible for the stress-strain relation to remain linear under such circumstances. It thus seems to me, on various grounds, that the inevitable conclusion is that while one or other of the two theories may, under ordinary circumstances, be sufficient to define the limits of the mathematical theory, the result must always be checked by reference to the condition (C), or, what comes to the same thing, we must give up the mathematical theory when the strains it indicates are such as would markedly alter the mean molecular distance.

I next proceed to discuss the possibility of the earth's possessing an elastic solid structure, deriving the necessary data from three papers published in the *Transactions of the Cambridge Philosophical Society*. For brevity these will be referred to as (*a*),* (*b*),† and (*c*).‡

The strains due to the action of the sun and moon being comparatively insignificant, we need consider only the "centrifugal" forces due to the earth's diurnal rotation, and the gravitational forces due to the mutual attraction of its parts.

The data supplied by geology do not enable us to formulate any likely theory as to a probable distribution of density and elasticity throughout the earth regarded as an elastic solid. All we know with certainty is that the surface strata are on an average considerably below the mean density, that they differ widely in character, many being markedly æolotropic, and that frequently they are far from horizontal. Thus, as our object is merely to consider what are the possibilities on the hypothesis of solidity, it will be best to make the hypothesis as simple as possible. Now, if the deviations from the earth's mean density and from an isotropic elastic structure were limited to the surface strata, where alone we are certain of their existence, the effect of the "centrifugal" forces would be nearly the same as if these deviations did not exist; but the effect of the gravitational forces on the eccentricity of the surface may depend largely on the nature of the deviations. I thus propose to treat the problem in stages.

The first stage neglects entirely the gravitational forces and regards the earth as a slightly spheroidal body—which has departed from the spherical form in consequence of its rotation—of uniform density and

* Vol. XIV, pp. 250–369. † Vol. XIV, pp. 467–483. ‡ Vol. XV, pp. 1–36.

of the same isotropic elastic structure throughout, rotating with uniform angular velocity $\omega$ about its polar axis.

Let $a$ denote the mean radius, $d$ the difference between the equatorial and polar semiaxes of the surface, E Young's modulus, and $\eta$ Poisson's ratio for the material. Then the ratio $d:a$ is given for various values of $\eta$ in the following table:*

TABLE I.

| $\eta =$ | 0 | 0.2 | 0.25 | 0.3 | 0.4 | 0.5 |
|---|---|---|---|---|---|---|
| $\frac{d}{a} \div \frac{\omega \rho a^2}{E} =$ | 0.286 | 0.330 | 0.341 | 0.352 | 0.373 | 0.395 |

In the case of an originally spherical solid assuming the shape of the earth under rotation, it is of no practical importance whether we regard $a$ as the radius of the original spherical surface, or as the mean radius under rotation, nor does it matter practically whether the density be supposed uniform previous to or during the rotation. There is, it is true, for all values of $\eta$ except 0.5, a slight increase in the volume,† and consequent diminution in the mean density accompanying the rotation, but for our present purpose this may be neglected.

The mathematical solution on which Table I is based treats the spherical surface of radius $a$ as that over which the conditions for a free surface are satisfied. Now, some uncertainty may exist, depending on the physical interpretation put upon the mathematical equations, whether these surface conditions should be applied over what is the surface before the displacement—in this case the surface of the true sphere which it is assumed the earth would form if the rotation disappeared—or over what is the surface during the rotation. This uncertainty might constitute a very serious difficulty if the deformations were supposed to be large, a contingency which may arise when the limitation (C) in the magnitude of the strains is neglected; but in such problems as the present where the strains are, as we shall see presently, of the same order of magnitude as occur in ordinary engineering structures, it is of no material consequence. In the present case complete assurance on this point may be derived from Figs. 1 and 2, Pl. II of (c), which show the changes induced by rotation in the equatorial and polar semi-axes of spheroids of various shapes.

For given values of $d$, $a$, $\omega$, and $\rho$, Table I shows that E and $\eta$ increase together. Giving $\omega$ the value it has for the earth, and assuming $\rho=5.5$, $a=3950$, $d=13.25$, I find for the values of E, measured in grams weight per square centimeter, answering respectively to the values 0, 0.25, and 0.5 of $\eta$, the approximate numbers

$$1020 \times 10^6, \quad 1220 \times 10^6, \quad \text{and} \quad 1410 \times 10^6$$

* See (a) formula (5) p. 287; or (c) Tables III, V, and VI.

† See (b) Table II, and compare Tables V and VI of (c).

It is obvious from Table I that to equal increments in $\eta$ there correspond nearly equal increments in E; thus the numbers given above will enable a sufficiently close approximation to the value of E for any other value of $\eta$ to be immediately written down.

For the sake of comparison with the values found for E in some of the commoner materials under ordinary conditions I append the following data, taken from Sir W. Thomson's article on Elasticity in the Encyclopædia Britannica. The units are the same as above.

TABLE II.

Values of $E/10^6$.

| | Iron and steel. | Copper. | Slate. | Zinc. | Stone (about). | Lead. |
|---|---|---|---|---|---|---|
| Highest value .... | 2953 | 1254 | 1120 | 955 | 350 | 199 |
| Lowest value ..... | 984 | 1052 | 910 | 873 | ........ | 51 |

This table will give a general idea of the limits within which E may reasonably be expected to lie, though some of the data refer to material which is hardly likely to have been isotropic. It shows that if the influence of the gravitational forces on the eccentricity were negligible,—which however is not the case,—the earth, though perfectly solid and elastic, might reasonably be expected to display not a smaller, but a considerably greater eccentricity than it actually does.

The question next arises whether the strains and stresses produced by the rotation are such as are consistent with the principles on which the application of the mathematical theory rests. In the actual case of the earth this question is of importance only in exceptional circumstances, owing to the preponderating influence of the gravitational forces; still it possesses sufficient interest to claim separate consideration. The following table gives a sufficiently close approximation to the numerical results obtained for the rotating body treated above, when for E are substituted the values which answer to the production by rotation alone of an eccentricity equal to that of the earth.

TABLE III.*

| $\eta =$ | 0 | ·25 | ·5 |
|---|---|---|---|
| Maximum stress-difference in tons weight per square inch .......................... | $32\frac{3}{4}$ | $32\frac{1}{4}$ | 32 |
| Greatest strain .......................... | 0·0040 | 0·0029 | 0·0018 |
| Longitudinal stress in tons per square inch which would produce a strain equal to the greatest strain .............. | 26 | 23 | 16 |

* See (c) Tables III, VII, and IX.

The maximum stress-difference and the greatest strain, as given in the table, are both found at the center.

The result on the stress-difference theory is nearly independent of $\eta$, and is more unfavorable in every case than that given by the greatest strain theory to the view that the material remains perfectly elastic. A stress of 16 tons per square inch is not one that an engineer would view with complacency in any structure intended to be permanent, but it is a low value for the tenacity of good wrought iron. A stress of even 33 tons per square inch can easily be borne without rupture by good steel, and is perhaps not in excess of the stress under which the best steel remains perfectly elastic. The greatest strains are not of such a magnitude as to raise any presumption against the linearity of the stress-strain relation. Thus, according to all the tests, it is quite possible that an originally spherical solid of the earth's mass but devoid of gravitation should remain solid and elastic while assuming the form of the earth under rotation. Its material, however, at least if homogeneous and isotropic, would require to possess an unusually high limit of perfect elasticity.

The next subject for consideration is how the question is affected by the existence of gravitational forces such as are found in the case of the earth. The strains and stresses in a slightly oblate spheroid, treated as an isotropic elastic solid, all consist of two parts, the first part being the same as if the surface were truly spherical, the second depending on the eccentricity. It is the second parts that represent the action of the gravitational forces in modifying the eccentricity, but these parts are in general insignificant so far as the question of the applicability of the mathematical theory is concerned. I shall therefore postpone consideration of them until an account has been given of the strains and stresses which are independent of the eccentricity.

The mathematical difficulties in applying the ordinary theory to the case of a homogeneous solid gravitating sphere are trifling, but the difficulty of putting a physical interpretation upon the mathematical expressions answering to most values of $\eta$ is such as very forcibly to call attention to the necessity of the limitation (C). Since the gravitational force at an element of a solid sphere depends not only on the total mass which lies nearer the center than does the element, but also on its absolute distance from the center, we must assume that the equations supplied by the ordinary mathematical theory, if they apply at all, hold for the position of final equilibrium after the deformations have taken place. This seemingly requires that strain should be defined as the ratio of the increase of length to the final length, which is not in accordance with the usual interpretation of Hooke's law unless the square of the strain be negligible. Supposing the internal equations to refer to the final deformed condition, the surface equations will undoubtedly also refer to this condition. Thus, so far as the terms independent of the eccentricity are concerned, we may suppose the mathematical theory

applied to a sphere whose density $\rho$ is uniform throughout, and whose radius $a$ equals the earth's mean radius.

In this case the maximum stress-difference and the algebraically greatest strain are both found at the surface. Let us denote these by $\bar{S}$ and $\bar{s}$ respectively; and let $s_0$ denote the greatest compression, which occurs at the center, and $u_a$ the radial displacement at the surface. Employing E and $\eta$ as before, and denoting by $g$ the acceleration due to the sphere's attraction at its surface, I find*

$$\bar{S}=\frac{1}{5}g\rho a\frac{1-2\eta}{1-\eta}, \quad (1)$$

$$\bar{s}=\frac{2}{5}\frac{g\rho a}{E}\frac{\eta(1-2\eta)}{1-\eta}, \quad (2)$$

$$s_0=-\frac{3}{10}\frac{g\rho a}{E}\frac{(1-2\eta)(1-\eta/3)}{1-\eta}, \quad (3)$$

$$u_a=-\frac{1}{5}\frac{g\rho a^2}{E}(1-2\eta) \quad (4)$$

Assuming for a moment these results to hold for a sphere in which $g$ = gravity† at the earth's surface, $\rho=5{\cdot}5$ times the density of water, and $a=3950$ miles, the following are the approximate numerical values answering to the values 0, ·25, and 0·5 of $\eta$:

TABLE IV.

| $\eta=$ | 0 | 0·25 | 0·5 |
|---|---|---|---|
| $\bar{S}$, in tons weight per square inch | 4440 | 2960 | 0 |
| Longitudinal stress E $\bar{s}$, in tons weight per square inch, which would produce a strain $\bar{s}$ | 0 | 1480 | 0 |
| $-s_0$ (see below) | 1·03 | 0·53 | 0 |
| $-u_a$, in miles (see below) | 2700 | 1130 | 0 |

For a given value of $\eta$ the value of $\bar{S}$ is independent of E. It diminishes continually as $\eta$ increases from zero. Since the value of $\bar{s}$ depends on E, I have given the value of E$\bar{s}$, or the longitudinal stress which would produce in a bar of the material a strain equal $\bar{s}$. The value of E$\bar{s}$ has a maximum of about 1,520 tons weight per square inch, for $\eta=1-\sqrt{1/2}$ or 0.293 nearly.

For $\eta=0{\cdot}5$ the values $s_0$ and $u_a$ are zero supposing E finite, but for other values of $\eta$ one can obtain numerical measures of these quantities only by assigning numerical values to E. Now, if the earth were an elastic solid truly spherical but for its rotation, the value of E answering to a given value of $\eta$ would be determined from the eccentricity of the surface. But the action of the gravitational forces, as will be seen

* See ($a$) formulæ (17), (18$a$), and (19$a$), p. 281.

† The calculations treat the attraction on a cubic centimeter of water at the surface as equal to the weight of 1 gram. In reality of course "gravity" includes the "centrifugal" force.

more clearly presently, largely reduces the eccentricity which rotation would produce in a sphere of given material. Thus the eccentricity varying inversely as E, the value of E answering to a given eccentricity is necessarily considerably smaller when gravitational forces act along with the "centrifugal" than when the latter act alone. Since the surface strata are very variable and of much smaller mean density than the earth as a whole, any calculation of the reduction of our estimates of E, when gravitational forces are allowed for, which treats the earth as of uniform density can not lay claim to great accuracy. For this reason, and also because I am specially desirous not to overstate the case against the application of the mathematical theory, I have, in calculating the values of $s_0$ and $u_a$ in Table IV, ascribed to E the values it would possess in the total absence of gravitational forces, viz., the values $1020\times10^6$ for $\eta=0$ and $1220\times10^6$ for $\eta=0{\cdot}25$ in the same units as before. The numerical values ascribed to $s_0$ and $u_a$ in the table are thus essentially minima, which would in reality have to be increased probably to a considerable extent.

It will be seen from the formulæ and from Table IV that when $\eta$ is zero or is small, the application of the mathematical theory would be fully justified on the greatest strain theory, while utterly condemned on the stress-difference theory. The principle (C) is in this case entirely in agreement with the stress-difference theory, and the application of the mathematical theory can in fact be supported only by those who reject this principle, and consider it possible for the stress-strain relation to remain linear though a solid sphere is reduced to one-fourth or less of its original volume.

Noticing from (1) and (2) that $Es/\bar{S}=2\eta$, we see that for all values of $\eta$ less than 0·5 the stress-difference theory is less favorable to the view that the mathematical theory is applicable than the greatest-strain theory. If there is any truth in either theory, the earth's material can not possibly possess a linear stress-strain relation for values of $\eta$ such as 0·25 (*i. e.* with a structure such as that of the metals) unless it be of a strength compared to which that of steel is insignificant. For such values of $\eta$ the strains are also enormously in excess of those which can be admitted according to the principle (C).

When, however, $\eta$ approaches the limiting value 0·5 a complete change comes over the features of the case. The maximum stress difference and all the strains diminish, eventually vanishing when $\eta=\cdot5$. Thus none of the objections hitherto encountered can be urged against the application of the mathematical theory when $\eta$ equals or nearly equals 0·5. To the exact value 0·5 of $\eta$ there is, I admit, a physical objection, which would doubtless have been urged by Maxwell, viz, that, supposing Young's modulus to be finite, this implies the material to be absolutely incompressible. There is however no obvious

* Stewart and Gee, in their *Elementary Practical Physics*, vol. I, p. 192–195, give data from which they conclude that india-rubber is such a material.

physical objection to the hypothesis that the material is very nearly incompressible, *i. e.* that $0{\cdot}5-\eta$ is very small;* and an isotropic sphere with such a structure would, according to all our tests, remain perfectly elastic when possessed of the earth's mass and exposed to its gravitational forces.

In our previous estimate of the value of E the action of the gravitational forces in reducing the eccentricity was not taken into account. If the principles we have laid down as regulating the applicability of the mathematical theory be conceded, we need only consider the case when $0{\cdot}5-\eta$ is very small; and since the formulæ show that in this case a small variation in the value of $\eta$ is of little consequence, we may for simplicity suppose $\eta=0{\cdot}5$ exactly.

In order to show the nature of the uncertainty that must in reality be attached to the result, it seems desirable to give a general idea of the way in which the existence of gravitational forces affects the eccentricity. Let us imagine, then, that over the surface of a perfect sphere weightless matter is piled up, which transforms the surface into that of a slightly oblate spheroid whose polar and equatorial semiaxes are respectively $a-2d/3$ and $a+d/3$. Now suppose the heaped-up material to become heavy. The pressure it exerts on the surface below it is greatest in the equator and is zero at the poles. Thus the originally spherical surface will tend to sink at the equator and to rise at the poles; consequently the difference $d$ between the equatorial and polar semiaxes of the sphroidal surface will diminish, but the diminution is clearly less the smaller the density of the heaped-up material.

It must be understood that this does not profess to be a complete account of what actually happens; but it may suffice to show that the gravitational forces tend to reduce the eccentricity which the centrifugal forces tend to develop, and also that this reduction may depend largely on the density of the surface layers. If the departure of the surface layers from the earth's mean density occurs mainly near the equator, then the action of the gravitational forces in reducing the eccentricity may be much less than it would seem to be on the hypothesis of an earth of uniform density.

Treating the density as uniform and $\eta$ as equal; $0{\cdot}5$, I find that, for a given value of E, the existence of the gravitational forces would in such a case as that of the earth reduce the difference between the equatorial and polar diameters called for by the rotation in the ratio of 9 : 40 approximately*. Thus, for a given eccentricity, the value of E when the gravitational forces act is to its value when the centrifugal forces alone exist as 9 : 40. So in the supposed case of the earth, we should have to reduce E from $141\times10^7$ to $32\times10^7$ grams weight per square centim. The maximum stress-difference reduces to 7·2 tons weight per square inch. The greatest strain remains 0.0018, as before, but it would answer to a purely longitudinal stress of only 3·6 tons per square inch.

*Cf. ($a$) formula (21), p. 283, and (5), p. 287.

Owing to the less density of the surface strata these reductions may be considerably too great, so that it is advisable to regard $32 \times 10^7$ as essentially a lower limit to the value of E. As stated above, the numerical result for the value of E would be but little altered if we supposed $\eta$ slightly less than 0·5; but unless $0·5 = \eta$ be very small, the terms independent of the eccentricity become of importance in estimating the maximum stress difference and greatest strain.

The conclusion to which the previous investigations leads is that none of the principles at present recognized in the biconstant theory of isotropy are opposed to the hypothesis that the earth possesses in its interior an isotropic elastic solid structure with a linear stress strain relation, provided its material be very nearly incompressible. But the hypothesis that the material in the interior shows an isotropic, elastic structure, such as that of the ordinary metals under the ordinary conditions, to which they are exposed on the earth's surface, can be maintained only by those who are prepared to reject the usual theories of the rupture, the limitation (C) in the size of the strains, and the argument introduced here from the theory of intermolecular forces. This raises no presumption against the hypothesis that the interior is in a perfectly solid state, and possessed of such a chemical constitution, say, as iron, if it be admitted that it is of a material in which the linearity of the stress-strain relation ceases when the compression becomes large.

The results obtained raise no presumption for or against the theory that the earth is in a liquid or plastic state. They merely show that any argument against the possibility of an elastic solid structure in a body of the earth's *form* is without foundation; and that any argument based on the destructive tendency of the enormous gravitational forces in a solid of its mass is inconclusive, even as directed against such structures as are compassed by the ordinary mathematical theory. It has not been shown that an æolotropic solid structure of some kind, or of a variety of kinds, may not satisfy all the conditions as well as or even better than a nearly incompressible isotropic material. The presumption is, in fact, that the conditions may be satisfied in an infinite number of ways.

It must be borne in mind that there may be fatal objections to an elastic solid structure which do not arise immediately from the theory of elasticity. Such an objection may arise from the rapid increase with the depth shown by the temperature near the earth's surface. My principal reason for referring to this is to point out that the common argument against the production of fluidity by the high internal temperature (viz, an assumed raising of the melting point by pressure) has just as much weight for a nearly incompressible solid earth as for any other, because while the stress difference in such an earth is small the internal pressures are very large.

Before passing to the second part of the paper, I have to confess that

there is no reason to believe that some of the limitations assigned here to the application of the mathematical theory will be accepted by all or even by a majority of the elasticians. In fact, the mathematical theory has actually been applied by several recent writers under circumstances when most or all of the limitations proposed here are violated. For instance, this is to a certain extent the case in Prof. Darwin's paper* "On the stresses caused in the interior of the earth by the weight of continents and mountains." In the principal part of the paper he supposes $\eta=0.5$, when, as we have seen, none of the objections apply; but in his § 10, in order "to know how far the results - - - may differ, if the elastic solid be compressible," he supposes that while the rigidity constant is finite the bulk modulus is very small. In other words, he applies mathematical formula which assume $\eta$ as nearly equal to $-1$. Such a value has been here regarded as impossible. It should also be noticed that if $\eta$ were equal $-1$ then E would vanish, and if $\eta$ be nearly $-1$ the value of E must be very small. Thus the strains and displacements given by equations 2 to 4 would, in the case supposed by Prof. Darwin, be enormously greater than even those given in Table IV. I do not observe, however, that either in the paper itself or in one supplementary† to it Prof. Darwin makes any explicit reference to the terms in the strain independent of the angular co-ordinates, from which the equations 1 to 4 are derived. I am thus unable to say whether his neglect of the limitations that these terms are here regarded as setting to the application of the mathematical theory is intentional or not. Again, in a recent paper‡ "On Sir William Thomson's estimate of the rigidity of the earth," Mr. Love has also considered the problem of the earth treated as an isotropic elastic sphere, more especially for the value of 0.25 of $\eta$. In his equations 14 and 18 Mr. Love determines the values of two arbitrary constants which occur in the terms independent of the angular co-ordinates, and it is easily seen that the expression he would thence obtain for these terms is identical with mine.§ After determining the second constant he however dismisses the subject with the remark, "This - - - gives the mean radial displacement, a matter which need not detain us here." So far as I can see, Mr. Love makes no reference to any principle such as C, nor to the possibility of the stress-strain relation ceasing to be linear.

I ought also to explain that in my paper (*a*), directing my attention solely to the theories of rupture, I left out of sight any such limitation as (B) or (C), and treated the case of an earth in which $\eta=0$ as one in which, according to the greatest-strain theory of rupture, the mathematical theory was applicable. I also failed to notice that the case $\eta=0.5$ was sanctioned by the greatest-strain theory as well as by the stress-difference theory.

* *Phil. Trans.*, 1882, pp. 187–230.

† *Proceedings of the Royal Society*, vol. XXXVIII (1885), pp. 322–328.

‡ *Trans. Camb. Phil. Soc.*, vol. XV, pp. 107–118.

§ (*a*) Equation (17), p. 281.

## II.—SOME GEOLOGICAL THEORIES.

The belief that the present spheroidal *form* of the earth necessarily betokens a previous liquid, or at least, plastic, condition seems among geologists almost as universal as the belief that the earth but for the development of rotation must have been a spherical body. Whether this latter conclusion has any satisfactory basis apart from philosophical speculations it is not my present object to inquire. But supposing, for the sake of argument, that the natural form of the earth as undisturbed by rotation is spherical, the conclusion that it ever was in a liquid or even in a plastic state throughout is, according to the preceding results, not established by its present spheroidal form. Yet even in such a standard work as Geikie's *Text-book of Geology*, after reading the discussion on p. 12 and the foot-note attached, I fail to detect a trace of the idea that the polar flattening might be called forth by rotation in a truly solid body.

Various geological writers, it is true, speak of a solid earth as capable of changing its form, but they seem in reality to regard the change as due to rupture or to the development of a plastic condition. This appears, for instance, to be the view actually held by Mr. Herbert Spencer in a short paper * entitled "The Form of the Earth no proof of Original Fluidity." This paper has been referred to with a somewhat inaccurate conception of its value and results by two recent geological writers, so it claims some notice at our hands. The first of the two writers referred to, Mr. W. B. Taylor,† says: "It is now nearly forty years since Herbert Spencer, with a juster physical insight [than Sir W. Thomson and Prof. Tait], contended and satisfactorily showed that a solid earth (of any shape) would assume the oblate spheroidal form due to its rate of rotation, as certainly and promptly as if it were liquid." The other writer, Mr. A. Blytt,‡ amongst other references to the paper says, "I believe that Spencer is the first who expressed the opinion that even a solid earth can change its form."

Mr. Spencer, after some statements as to the relative strength and agility of large and small animals, such as elephants and fleas, formulates the general result that the strength—called also "resistance to fracture"—of a solid structure varies as the square of its linear dimensions, while the "agencies antagonistic to cohesive attraction," *i. e.*, gravitational and "centrifugal" forces, etc., vary as the cube. Excepting a statement that this is obviously true of simple longitudinal and torsional stress, the following is the sole proof of his very general law supplied by Mr. Spencer: "The strength of a bar of iron, timber, or other material subjected to the transverse strain varies as $BD^2/L$; B

* *Phil. Mag.*, 1847, [3] vol. xxx, pp. 194–196.

† *American Journal of Science*, 1885, vol. xxx, pp. 258, 259.

‡ *Phil. Mag.*, May, 1889, p. 415. Translated from *Nyt Magazin for Naturvidenskaberne*, 1889, Bd. xxxi. *Smithsonian Report*, 1889: p. 333.

being the breadth, D the depth, and L the length. Suppose the size of this bar to be changed, whilst the ratios of its dimensions continue the same; then - - - the strength will vary as $D^2$ - - - " (p. 195). The following is the conclusion drawn by Mr. Spencer: "Viewed by the light of this principle, the fact that the earth is an oblate spheroid does not seem to afford any support to the hypothesis of original fluidity as commonly understood. We must consider that in respect of its obedience to the geo-dynamic laws, the earth is fluid now and must always remain so; for the most tenacious substance with which we are acquainted, when subjected to the same forces that are acting upon the earth's crust, would exceed the limit of self-support determined by the above law, before it attained $\frac{1}{1,000,000,000}$ of the earth's bulk" (p. 196).

Perhaps if one knew what Mr. Spencer means by "the limit of self support," and what is the exact distinction he draws between "fluidity as commonly understood" and "fluidity in respect of obedience to geo-dynamic laws," one might be in a position to form some estimate of his degree of physical insight; but so far as I can see all he satisfactorily shows is an extraordinary agility in jumping to conclusions. If his meaning is that deformation must accompany the action of gravitational and centrifugal forces, he might, if Maxwell's view be correct, have added to the denominator of his estimate as many 0's as the printer could spare; but if it is the rupture of an elastic solid or its transformation into a plastic state to which he refers, as seems almost certain from the context, he must have formed an extremely low estimate of what strains a solid can stand.

In the same passage Mr. Blytt refers to Mr. Peirce,* Sir J. W. Dawson,† and Prof. J. E. Todd ‡ as holding that a solid earth will alter its shape if the rate of rotation vary. The views of Mr. Peirce I have not seen, but the other two writers mentioned regard the solid earth itself as changing shape only by means of a succession of what we may term catastrophies. Their views seem identical with those which Mr. Blytt's translator ascribes to him in the following words: "The sea adjusts itself in accordance with the smallest change in the length of the day - - - But the solid earth offers resistance to change of form, and begins to give way only when the tension reaches a certain amount" (p. 418). Mr. Blytt makes several distinct references to the subject, and his remarks are not perhaps always strictly consistent. This, however, is hardly to be wondered at, since he gives as the result of his investigations: "As has been stated, there prevails - - - a disagreement as to how far the earth will change its form, in case the centrifugal force varies. Thomson is most inclined to believe that it will not. Darwin is of opinion that it will. And among other physicists whom I have consulted a similar divergence prevails upon this point. One thinks

* *Proc. Amer. Acad. Arts and Science*, 1873, vol. VIII, p. 106.

† *Story of the Earth and Man*, ninth edition, pp. 291, 292.

‡ *American Naturalist*, 1883, vol. XVII, pp. 15-26, specially pp. 18, 19.

that a lengthening of the day even by several hours will be incapable of altering the form of the solid earth; another believes that the solid earth will probably change its form just as easily as the sea" (p. 421).

If Mr. Blytt should ever have further occasion to consult physicists on this or any allied point, he would find an exact definition of such terms as *solid* a certain amount of protection from *á priori* speculations. Mr. Blytt's own principal view seems due in part to an erroneous interpretation of Tresca's experiments on the flow of metals under pressure. They do not in reality justify his statement "By reason of the enormous pressure which prevails in the interior of the earth, it must be supposed that masses from a certain depth are more or less in a plastic state" (p. 417). It was in fact pointed out some years ago by the Rev. Osmond Fisher * that the existence of an orifice from which the metal can flow constitutes a complete difference between the conditions of Tresca's experiments and the state of a body subjected to nearly uniform pressure all round.

Mr. Blytt apparently does not stand alone in believing Sir W. Thomson to hold that the solid earth is incapable of altering its form as the rotation alters, and that it possesses the same eccentricity as when it solidified. Prof. Darwin in *Nature*, 1886, vol. XXXIV, pp. 420–423, seems also to put this interpretation upon a passage he quotes from § 830 of Thomson and Tait's "*Natural Philosophy.*" Supposing this interpretation correct, Prof. Darwin's opinion that Sir W. Thomson does not allow "a sufficient margin for uncertainties" expresses only a part of the objections I should entertain. I find it difficult however to believe that Sir W. Thompson, who elsewhere gives data for the eccentricity produced by rotation in solid spheres of steel, can actually suppose no change at all in the eccentricity to follow an alteration in the angular velocity. Still it must be confessed that though the passage contains the statement, "It must necessarily remain uncertain whether the earth would from time to time adjust itself completely to a figure of equilibrium adapted to the rotation," its most natural interpretation is that given by Prof. Darwin. I need hardly say that the conclusion that the earth, however solid, would retain a constant eccentricity while the rate of rotation varied, seems to me directly opposed to the conclusions to which the elastic solid theory leads.

Prof. Darwin himself, in his paper in *Nature* refers to Tresca's experiments and thinks it probable there would be from time to time a flow of material as the angular velocity altered. One of the "uncertainties" he refers to is the possibility that, in accordance with Dr. Croll's† views, a greater rapidity of denudation in equatorial than in polar regions may have reduced the eccentricity markedly below the value it possessed when the earth solidified. He does not seem however to

* *Physics of the Earth's Crust*, 1st edition, 1881, foot-note p. 120.

† *Climate and Time* (1885), p. 336.

refer to the considerable change of eccentricity that might occur in a solid through mere variation of elastic strain.

As regards the present state of the earth's interior there are, according to Geikie's Text-book, p. 49, only three theories which merit serious consideration, viz:

(1) That there is a solid crust and a molten interior.

(2) That with the exception of local vesicular spaces the earth is perfectly solid.

(3) That the earth consists of a solid crust and nucleus with an intervening liquid layer.

According to the Text-book, the theory of a thin crust containing liquid or viscous matter is exposed to "weighty and indeed insuperable objections," p. 18, and "is now abandoned by most geologists," p. 43.

According to Dr. Croll * the "general opinion among geologists" is that the earth "consists of a fluid interior surrounded by a thick and rigid [really solid] crust."

Prof. Prestwich † believes that "the crust rests on a yielding substratum, and that of no great thickness." In fact he advocates the third of the above-mentioned theories, and believes 30 miles to be probably in excess of the crust's thickness. Most writers on the subject appear to have subsidiary theories of their own.

Whether the assurance that the question is beyond the reach of experiment accounts for the multitude of theories and the confidence with which they are proposed, is a question for philosophers not mathematicians to consider, but it seems *a priori* a possible explanation of such a declaration of faith as that of Mr. W. B. Taylor: ‡ "The liquidity of our globe, and the relative thinness of its encrusted envelope—as attested by all legitimate *geological* induction—will be assumed without misgiving or hesitancy, and the supposed matematical arguments for its solidity ignored as essentially fallacious and wholly inconclusive."

Of course if the geological evidence were conclusive, it would be mere waste of time further to consider the matter, but the evidence that satisfies Mr. Taylor does not seem to carry conviction to all geologists even in America. Mr. G. Becker,§ for instance, who appears to have same practical experience, says: "For a considerable number of years I have constantly had the theory of the earth's solidity in mind while making field observations on upheaval and subsidence, with the result that to my thinking, the phenomena are capable of much more satisfactory explanation on a solid globe than on an encrusted fluid one."

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* *Climate and Time*, p. 395.

† *Geology*, vol. II, p. 540.

‡ *American Journal of Science* (1885), vol. XXX, p. 250.

§ *American Journal of Science* (1890), vol. XXXIX, pp. 351, 352.

It may thus be not wholly unprofitable to glance briefly at some of the arguments which some of the advocates of the several theories base on their ideas of the properties of solid bodies.

Mr. Taylor's object is to get an equatorial circumference some 10 per cent in excess of its present value, so as to account for the lateral compression at the surface observed in mountain chains. Thus, following Prof. Darwin,* he supposes the earth to have once possessed a much greater angular velocity than at present, and speaks of a "consistent crust (of some few miles thickness)" as having formed "when the rotation of our planet was at four times its present rate" (*l. c.*, p. 257). The equatorial radius would then have been, he says, some 4,359 miles, and the polar some 3,291. The change of shape, as the rotation fell off, would account, he thinks, for observed phenomena. He considers his conclusions opposed by Sir W. Thomson's theory that the earth solidified throughout and retains at least approximately its original eccentricity. It is on this point that he refers to the data supplied by Mr. Herbert Spencer's "juster physical insight;" and he adds, apparently as his own contribution to the argument, "the supposition that a granite mountain or equatorial protuberance 400 miles high or 100 miles high could for a moment support itself, would hardly be entertained by a practical engineer;" and in a foot-note, "the limiting modulus of height of a granite pyramid (equalling one side of its square base) is somewhat less than 11 miles" (*l. c.*, p. 258). I am quite ready to agree with Mr. Taylor that if solidification occurred under the conditions he supposes the eccentricity must have altered enormously and that in a non-elastic way, and I hardly suppose that Sir W. Thompson would oppose this view. No one however so far as I know, has propounded the theory of an elastic solid spheroidal earth of eccentricity 0.65 rotating completely in six hours, so that the investigation of the strains and stresses required by such a theory is unnecessary. I can quite imagine that on any probable theory of density the magnitude of the strains is hardly likely to be consistent with the application of the mathematical theory of elasticity. The force of Mr. Taylor's remarks as to the pyramid I, however, fail to see. Such an isolated mass exists under totally different conditions from any portion of a solid sphere or spheroid, and one might as well argue as to the impossibility of a liquid interior from the fact that an isolated liquid column 100 miles high has not yet been observed on the earth's surface. If Mr. Taylor were however to calculate the strains and stresses in such a thin shell as he supposes, of material showing anything resembling the structure of ordinary rock, with a rate of rotation such as he mentions, I very much doubt whether he would find it in an essentially better position than his imaginary pyramid.

After this criticism Mr. Taylor considers the question of the probable degree of rigidity of our planet quite irrelevant, but the "temptation is

* *Phil. Trans.* (1879), p. 532.

strong to waste upon it a collateral glance" (*l. c.*, p. 259). Accordingly he crushes Sir W. Thomson's argument * from the tides by the remark, "that a siliceous crust of 20 miles average thickness and an overlying aqueous ocean of 3 miles average depth, should have (as required by the argument) so equal a coefficient of mobility that sea and land could thus together 'rise and fall,' might well be pronounced incredible" (*l. c.*, p. 260).

He regards Sir W. Thomson as very seriously damaging his own argument by the admission that tides comparable in magnitude with those observed would occur even in a solid earth of steel. It does not seem to have occurred to him that the existence of a difference between the motions of the land and water may constitute an argument for solidity.†

Mr. Taylor admits one difficulty in his theory, viz, the nature and local characteristics of the plications actually observed, and remarks: "While the force at the command of the rotating planet is abundantly sufficient - - - evidently some supplementary considerations are requisite to give the observed direction to this force," - - - "The mere mechanical difficulty however of transmitting stresses through comparatively undisturbed areas of hundreds of miles of a flexible, friable, and practically plastic crust—with a large coefficient of viscous friction beneath—is not so formidable as might at first appear. It must be borne in mind that the pressures derived from an action so slow as from century to century to be scarcely sensible, are of an order of very great intensity, but of very small quantity" (*l. c.*, p. 265). Mr. Taylor also infers from "various considerations" that "in all ages mountain building has been at a maximum; that is, the uplifted heights have been the greatest which the average thickness of the crust at the time was capable of supporting; so that the former has been a constant function of the latter, the ratio being probably not far from one-fifth" (*l. c.*, p. 265). Mr. Taylor does not state that this law of the uplifted heights is true of all lands as well as of all time, but the possibility that such may be the case is rather alarming. He enters in fact into no unnecessary details as to how he reached his conclusions, so that all one can say is that, measured by his own standard, he is certainly not inferior in physical insight even to Mr. Herbert Spencer. Perhaps when he comes to deal with the "supplementary considerations" he may supply sufficient data for the mathematician to follow him.

Prof. Prestwich, in his Geology, vol. II, regards the "present very great rigidity of the earth" as being proved by mathematical and physical investigations; but complains of a "want of elasticity" in the methods of the mathematicians (p. 538). According to him, "the hypothesis most compatible with the geological phenomena is that of a central solid nucleus with a molten yielding envelope—not fluid, but viscid or plastic; nor is it necessary that this magma should be of any

* *Natural Philosophy*, Vol. I, part II, § 833.

† See his remarks, *l. c.*, p. 260, and foot-note.

great thickness; but a thin crust is, it seems to me, an essential condition" (p. 543). Prof. Prestwich adduces in support of his views various arguments from geological phenomena which seem of much weight. He has also various arguments of a more or less physical character, but they seem to take a good deal for granted. Thus, on p. 540, referring to plications in the surface rocks, he says, "if the earth were solid throughout, the tangential pressure would result not in distorting or crumpling, but in crushing and breaking. As a rule, no such results are to be seen, and the strata have - - - yielded, as only a free surface plate could, to the deformation caused by lateral pressure - - - a yielding bed, on which the crust could move as a separate body, was necessary." It seems to me that as the phenomena of rupture are as yet very imperfectly ascertained, except perhaps for a few simple standard conditions, Prof. Prestwich has very little to go on but *à priori* ideas. I fail to see, for instance, why pressures at or near the surface of a solid sphere should necessarily produce fracture and not flow. Also it seems improbable that there would be a sharp line of demarcation so as to enable a crust—which seems clearly to mean a solid superficial layer—to move as a separate body on a "yielding bed." Would not this imply a liquid substratum with no appreciable viscosity? And supposing there were a substratum of this kind, is there any sufficient experimental evidence that a solid crust of even a few miles thickness would, on the falling away of the liquid underneath, go into folds instead of being crushed and broken? Further, can plications to the extent shown, say by the Alps, be reconciled with the retention of contemporaneous solidity? Supposing the earth to be essentially solid throughout, is there any reason why the strain at some miles below the surface should not locally at intervals exceed the elastic limit, with the result for a time of a state of flow or plasticity throughout a volume of greater or less extent? During such an epoch there would exist locally conditions somewhat resembling those which Prof. Prestwich believes existent everywhere. It is true that one argument adduced by Prof. Prestwich and others against the existence of separate reservoirs of molten material, viz, the similarity in the character of volcanic products all over the earth, applies equally against such an hypothesis. If however volcanic products be supposed to come from several miles below the surface, I see no obvious reason why they should not present similar characteristics everywhere. No conclusive argument can well be based on the differences observed in the sedimentary strata, because the conditions under which such strata are deposited are obviously of a varied character.

In various passages of Prof. Prestwich's discussion of the state of the earth one is apt to be puzzled by his falling into the practice, by no means uncommon in geological writings, of employing physical terms with a view to oratory rather than to exposition. For instance, he speaks of contraction "due to the yielding of the weaker lines in the

crust, when the tension caused by the excessive strain (and of which the first order of movement is an index) overcomes the resistance, and fractures and doubles up the strata;" and he adds: "Mountain ranges are in fact the concluding term of the stress which caused the deformation of the crust, and the movements which at those times took place must have been influenced by the greater energy of the strains then at work" (p. 546). It is difficult to see here what is intended to be cause and what effect. In fact, while a number of terms are employed which in mathematics and physics have a fairly definite meaning, I must confess my inability to form an adequate conception of what is meant by the passage as a whole.

Prof. Prestwich refers (pp. 543, 544) to the hypothesis of the late Prof. E. Roche (in the reference to which a misprint gives the year 1861 for 1881) as supplying something of the kind of earth he wants. Thus an examination of Prof. Roche's work* may be of some service.

He supposes the earth to consist of a central nucleus or "bloc," homogeneous but for a possible accumulation of matter of greater density at the center, and of a superficial layer of lighter material. Of the nucleus, with the possible exception of a small core of heavier matter, he says, "Sa densité calculée, de 7 à 7·5, indique qu'elle est métallique, sans doute formée de fer - - -" The specific gravity of the heavier matter which may possibly exist at the center is, he says, "certainement bien inférieur [to 18], probablement 10 ou 12 (argent, plomb)," p. 235. The outer layer or crust he supposes to have a specific gravity about 3, and a thickness of about one-sixth the earth's radius. Between the crust and the nucleus there exists, it may be everywhere or only locally, molten matter such as appears at the surface in volcanic outbursts, but the total volume occupied by this must be small. Prof. Roche takes three results as given, viz, the earth's total mass, the eccentricity of its surface, and the ratio of the principal moments of inertia, the last quantity being deduced from astronomical data. He satisfies all the conditions he recognizes by the aid of the following hypothesis regarding his nucleus: "Ce bloc a pris sa forme définitive sous l'influence d'une rotation moins rapide qu'elle n'est aujourd'hui, et il a conservé l'aplatissement correspondant, malgré les accroissements successifs de vitesse du système résultants de sa contraction progressive" (p. 232). In other words, he assumes the nucleus to have solidified before the crust and that it retains its shape unaltered. Thus as he regards the angular velocity as increasing in consequence of the diminution in the moment of inertia through contraction in cooling, the nucleus possesses a smaller eccentricity than the crust. He supposes only a small difference in the length of the day at the dates of the two solidifications, so that the difference between the eccentricities of the nucleus and crust is also small. This however in no way justifies his

*Académie - - - de Montpellier Mémoires de la Section des Sciences, 1880–1884, tome dixième, pp. 221–264.

hypothesis that the nucleus retains its form unaltered. If its material possessed the properties of an elastic solid the eccentricity would certainly alter, and to an extent probably quite comparable with the alteration that would have occurred if it had remained fluid. Prof. Roche seems in fact to treat his nucleus as possessed of the properties of the wholly imaginary perfectly rigid body. He certainly introduces no equations such as ought to hold over the surface of an elastic solid spheroid. The exact view he adopted as to the properties of solids it is, however, difficult to decide. On his page 241 a brief statement would imply that he did not regard each elementary layer of a solid sphere as of necessity totally self-supporting; but on pages 223, 224, where the discussion is fuller, he says, "Si l'on rejette la complète fluidité de la terre, il n'est plus possible d'attribuer à la compressibilité de ses couches la même influence." - - - "Dans un solide, les tensions latérales sont variables et acquièrent parfois une valeur énorme. C'est ainsi qu'une couche pourrait se soutenir d'elle même comme une espèce de voûte, sans peser sur celle qui est au-dessous." A solid layer supporting itself like an arch under the conditions of matter near the earth's surface treated as an elastic solid, presents strains far in excess of those which are regarded here as coming within the range of the mathematical theory.

On various grounds it seems to me that the criticism of a want of elasticity, though hardly in the sense intended by Prof. Prestwich, may be strongly urged against Roche's investigations.

Some remarks of M. Roche's, on his pages 240, 241, throw considerable light on his standpoint and that of many other theorists: "Les astronomes qui persistent à admettre la fluidité - - - cherchent à éluder les objections de Hopkins et de Thomson, en attribuant - - - au liquide central une viscosité assez grande pour que - - - l'ensemble en arrive à tourner tout d'une pièce - - - La masse tournante offre une telle rigidité qu'elle est assimilable sous ce rapport à un bloc solidifié, mais admettre cette assimilation revient à dépouiller le milieu interne des propriétés ordinaires des liquides, et à lui en conserver le nom tout en l'identifiant à un corps solide." He proceeds to point out that the mere question of a name is of no account, considering our ignorance of what would be the properties of matter under such pressures and at such a temperature as the theory of fluidity would lead to. His line of argument is not very clear, but there is no hesitation apparent in his conclusion: "En effet, la pression supportée par les couches centrales, dans la supposition d'une complète fluidité, dépasserait deux millions et demi d'atmosphères. La grandeur même de ce nombre est à elle seule une objection péremptoire à l'hypothèse qui y conduit.

Such a position as this may be all very well for a philosopher who supposes the external world a mere idea, the private property of his own mind and so necessarily obedient to laws which his understanding

can fully grasp, or for a scientist who believes the earth created for the special purpose of supplying problems of precisely that amount of difficulty which he personally is able to solve, but from a common-sense point of view it seems utterly irrational. No physicist or geologist has any reason to suppose that there are not numerous problems whose full comprehension requires more extensive knowledge than is possessed by himself or any of his contemporaries.

The necessity for theories has been eloquently urged by Prof. Darwin,* who says: "A theory is, then, a necessity for the advance of science, and we may regard it as the branch of a living tree, of which facts are the nourishment." Employing this simile, I must confess that the subject treated in this paper resembles, in my opinion, a tree which combines a sad deficiency of sap with a great superfluity of branches. It will I dare say be generally admitted that the premature craving after a finality of knowledge has been responsible for numerous fruitless speculations in the past, and it seems only too probable that the impatience of the mind with its own ignorance is the principal foundation of much of the theory of to-day. The satisfaction derived from the contemplation of simple and comprehensive laws may suffice perhaps to prove that the powers of the mind are limited, but hardly that the processes of nature are simple.

* *Nature*, 1886, vol. XXXIV, p. 420, Address to British Association, section A.

# ORIGIN OF THE ROCK PRESSURE OF NATURAL GAS IN THE TRENTON LIMESTONE OF OHIO AND INDIANA.*

By Edward Orton.

## THE IMPORTANCE OF THE PRODUCT.

Natural gas derived from the Trenton limestone has supplied during the last year and is now supplying all the fuel and a considerable part of the artificial light that is used by at least four hundred thousand people in northwestern Ohio and in central Indiana. Within the same limits it is the basis of a varied line of manufactures, the annual product of which will make an aggregate of many millions of dollars. More than forty glass furnaces, not one of them three years old, are now in very successful operation within the territory named, while iron and steel mills, potteries, and brick works, and a long list of factories in which cheap power is a desideratum, have been built up on all sides with wonderful rapidity.

The largest gas production of the Trenton limestone that has yet been reached is to be credited to the present year. A well, drilled early last summer at Stuartsville, 6 miles north of Findlay, produced through the casing, a pipe $5\frac{5}{8}$ inches in diameter, 28,000,000 cubic feet of gas every twenty-four hours. There are but few wells in any field that exceed these figures. Most of the wells so reported have been estimated, not measured.

An equally astonishing advance has been made in the oil production of this rock within four counties of northwestern Ohio. Single wells drilled during the last year have begun their production at a rate of 10,000 barrels per day, and more than 200,000 barrels of total production are already to be credited to single wells of the new field, while a considerable number have passed the 100,000-barrel mark.

## THE ROCK PRESSURE.

The rock pressure of the gas is a vital factor in all this production. To its energy is due the propulsion of the volatile fuel from the wells where it is released, through 20, 30, 50 miles of buried pipes, to the

* Read before the Geological Society of America, December 26, 1889. (From the *Bulletin Geolog. Soc. Amer.*, March 1, 1890, vol. I, pp. 87–94.)

cities which it supplies with the unspeakable advantages of gaseous fuel. It is the same cause that lifts the oil from the rock in all flowing wells.

By rock pressure is meant the pressure which a gauge shows in a well that is locked in after the drill has reached the gas reservoir. The iron tubing of the well becomes by this means a part of the reservoir, and the same conditions as to pressure are supposed to pertain to it that are found in the porous rock below.

The rock pressure of gas varies greatly in different fields and to a less, but still an important, extent in different portions of the same field. The highest rock pressure recorded in the Trenton limestone is about 650 pounds to the square inch, while there are considerable portions of the gas territory that never reach 300 pounds pressure per square inch. The original pressure in the Findlay field was 450 pounds, varying somewhat in wells of different depths. In the Wood County field, from which the largest amount of gas is now being conveyed to Ohio cities, the original pressure ranged from 420 to 480 pounds, the general pressure being counted 460 pounds to the square inch. There were occasional records made of still higher pressure in single wells, but of such cases the number is very small, and the existence of these anomalous pressures was short lived.

Passing to the westward, the gas wells of Auglaize and Mercer counties show a decided reduction in original rock pressure as compared with Findlay, though the depths of the wells remain the same as in that field. The highest pressure recorded in Mercer County is 390 pounds to the square inch, but no gauge was applied to the wells until they had been allowed to discharge without restraint for several months, while 375 and 350 pounds mark the extreme limit of other portions of this district.

In the Indiana field a still further reduction of rock pressure is to be noted. The range of the principal Indiana wells is between 250 and 325 pounds to the square inch. The Indiana gas wells, as compared with Ohio gas wells, are marked by a reduction in total depth, as well as in rock pressure, the figures for depth in the productive territory seldom or never passing 1,000 feet.

How can these variations be accounted for? Back of this question is a larger one, viz: What is the origin of the rock pressure of natural gas?

### THEORIES OF ORIGIN OF ROCK PRESSURE.

Considering its importance, the main question has received less consideration than would naturally be expected. The known literature of the subject is very meager. Prof. J. P. Lesley, in the *Annual Report of the Pennsylvania Survey* for 1885, discussed the question at greater length than any other geologist, so far as I know. In a paper pub-

lished in the *American Manufacturer*, May 27, 1887, I threw out a few suggestions as to the cause of rock pressure, and these suggestions I afterwards expanded into a more extended statement, in the sixth volume of the *Geology of Ohio*, p. 96. Prof. I. C. White reminds me that he suggested an explanation in the journal named above at an earlier date than either of those given.

The men who are engaged in the practical development of gas and oil fields make great account of rock pressure. It is the first fact that they inquire after in a new gas field. They appreciate its importance in whatever utilization of the gas they may propose, knowing that the distance of the markets that they can reach and the size of the pipes that they can employ are entirely dependent upon this element. These practical men, so called, are as is well known, among the most venturesome of theorists, and a question like this would not be likely to be left unanswered by them. A certain rough correspondence that exists between the depth and the rock pressure of wells is made of great account in explanations that they offer. In other words, the pressure is supposed to be due to the weight of the overlying rocks; and next to this we find among them the expansive force of gas the favorite explanation of the phenomenon.

In the paper of Prof. Lesley, already referred to, the learned author suggests the two possible explanations of rock pressure already named, and to this he adds a third, viz, hydraulic pressure; but he adds this explanation only to reject it as a true cause of the phenomenon under discussion. The absurdity of the more commonly received explanation of rock pressure, as due to the depth of the well—in other words to the weight of the overlying country—he sets in such clear light in his discussion that no further consideration of this is required on the part of those who are open to reason. Until we can prove, or at least render it probable, that the gas rocks have lost their cohesion and that they exist at the depths of storage in a crushed or comminuted state, no explanation can be based upon the weight of the overlying rock in accounting for the force with which the gas escapes from its reservoirs when they are penetrated by the drill. Prof. Lesley throws the whole weight of his authority in favor of the view that the gas "produces its own pressure like gas generated by chemical reaction in a closed vessel." This explanation certainly leaves something to be desired, for it fails to account for the most significant and important facts in this connection, viz, the difference of rock pressure in different localities and at different depths. To accept it, brings us no advantage whatever beyond the satisfaction that we may feel in having an answer at hand that can be promptly given to a troublesome inquiry.

For my own part, I have felt certain for more than two years that the rock pressure of gas in the Trenton limestone of Ohio and Indiana is hydrostatic in origin, and I have published a number of facts that seem to me to give support to this view. I find that some sagacious

operators in the new gas and oil fields are coming to the same ground. They have become thoroughly satisfied by their own experiences that the root of rock pressure is to be found in the water column that stands connected with the porous rock in which the gas and oil are contained. In the present paper I desire to present to the Geological Society a few facts and conclusions bearing upon the subject.

### THE DATA FOR THE HYDROSTATIC THEORY.

The first question is, What are the facts as to the rock pressures of the gas rock in question and what relations do they bear to the depth of wells and other conditions in the Trenton limestone? The answer is not as full and definite as may be expected, certainly not as may be desired. There is but one datum in the development of a gas field in which the normal gas pressure can be ascertained, and that is when the first well reaches the reservoir and releases the long-imprisoned and greatly compressed gas. But often this favorable opportunity is lost, and gauges are not applied to wells until the energy of the first flow is somewhat abated. Again, different wells in the same field, as Findlay, for example, give different results. The wells vary with the depth at which the gas rock is found. This factor is found to be an essential one, as will presently be shown, in connection with rock pressure. Moreover, gauges are sometimes inaccurate and their errors come in to confuse the study of the subject. Furthermore, the exact depth of the wells and the exact altitude of the surface where they are located can not be ascertained in all cases. Small errors of this sort must be provided for, and there also enters into the discussion a question as to the specific gravity of the water which is to be made the moving force of gas and oil. The water found in association with these substances is never fresh. It is always saline and often highly mineralized. The weight of fresh water to the square inch is 0.43285 pound for 1 foot in height (I use Professor Lesley's tables). The average weight of sea water is 0.445 pound to the square inch for 1 foot; but the mineral waters with which we find the Trenton limestone saturated often reach a much higher figure. An examination of several specimens shows that a column 1 foot high would weigh to the square inch 0.476 pound. In fact, some of these waters are more like bitterns, and their columns would equal or exceed 0.5 pound per foot.

Bearing these several sources of ambiguity or uncertainty in mind, we can consider the records of pressure, depth, and the other factors that are accessible. The figures as to pressure have already been summarized in a preceding paragraph, but they will be repeated in an accompanying tabular statement. Before coming to this, however, let me in the briefest terms review the conditions under which gas, oil, and salt water exist in the Trenton limestone. The uppermost beds of the great Trenton formation in northwestern Ohio, central and northern Indiana, Michigan, Illinois, and Wisconsin consist of a porous dolomite 5, 50, 100,

or even 150 feet in thickness. Sometimes the dolomite is found in a continuous body, but oftener in interrupted beds. This part of the formation has outcrops in the Manitoulin islands of Lake Superior and in the Galena limestone of Illinois and Wisconsin. In the gas and oil fields, it is found lying in terraces and monoclines, or flat arches, 800 to 1,500 feet below the surface; and these several features effect the separation of the varied contents of the porous rock, The boundaries of gas, oil, and salt water are easily determinable and are scrupulously maintained in the rock, except that as soon as development begins the salt water is always the aggressive and advancing element. When the drill descends into the gas rock proper dry gas escapes; when into the contiguous and lower-lying terrace, oil accompanied with gas appears, as already described; but at a little lower level salt water is struck, and this rises promptly in the well, sometimes to the point of overflow. Far out from the narrow ridges or restricted terraces where gas and oil are found the salt water reigns undisturbed, and wherever reached by the drill it rises in the wells as in those already described. It would be in the highest degree absurd to count the little pockets of gas that are found in the arches the cause of the ascent of this ocean of salt water a score or a hundred miles away. The rise of the salt water is unmistakably artesian. It depends on hydrostatic pressure, as does the flow of all artesian wells, and its head must be sought, as in other like flows, in the higher portions of the stratum that are contiguous.

The nearest outcrops of this porous Trenton have been already named. They are found in the shores of Lake Superior at an altitude of about 600 feet above tide. It is certainly significant that when an abundant flow of salt water is struck in a boring in northern Ohio or in Indiana, no matter at what depth, it rises generally about to the level of Lake Superior; or, in other words, about 600 feet above tide. If the mouth of the well is below this level, as is the case in the Wabash Valley, the salt water overflows. On the shore of Lake Erie the water rises to within 20 feet of the surface; in Findlay, to within 200 feet. The height to which the salt water rises in any portion of the field is one of the elements to be used in measuring the force which can be exerted on the gas and oil that are caught in the traps of the terraces and arches of the porous Trenton limestone.

Why, then, is not the rock pressure of the gas the same in all portions of the new horizon? For the obvious reason, I reply, that there is a varying element involved, viz., *the depth of the rock below sea level.* The surface elevations at the wells vary greatly, and the wells of the same depth consequently find the gas rock in very different relations to sea level.

## THE TEST OF THE HYDROSTATIC THEORY.

It is obvious that if an explanation of the rock pressure of the Trenton limestone gas is attempted on this basis, there are facts enough now at command to substantiate or overthrow it. By the facts it must

stand or fall. In the accompanying table I have indicated the following lines of facts as to strictly representative wells in the leading districts of the new gas fields, viz, (1) location, (2) depth at which gas is found, (3) relation of this depth to sea level, (4) the initial rock pressure of the gas. In regard to the last line of facts I have taken, in almost all cases, figures that I have myself verified. (5) A fifth column I add, in which the pressure due in the particular well is calculated from the two following elements, viz, an assumed elevation of the salt water to the Lake Superior level, or 600 feet above tide; and, secondly, an assumed specific gravity of the salt water of the Trenton of 1.1, which gives a weight of 0.476 pound to the foot.

| Locations. | Depth to gas. | Relation of gas rock to sea level (below tide). | Original or first observed pressure. | Calculated pressure 1 foot = 0.476 pound. |
|---|---|---|---|---|
| OHIO. | *Feet.* | *Feet.* | *Pounds.* | *Pounds.* |
| Tiffin, Loomis & Nyman well | 1,500 | 747 | 650? | 641 |
| Upper Sandusky, well No. 1 | 1,280 | 478 | 515 | 513 |
| Bloom Township, Wood County, Godsend well | 1,145 | 395 | 465 | 473.6 |
| Findlay, Pioneer well | 1,120 | 336 | 450 | 445.7 |
| St. Mary's, Axe well | 1,159 | 238 | 390 | 398.8 |
| St. Henry's, Dwyer well, No. 1 | 1,156 | 200 | 375 | 385 |
| INDIANA. | | | | |
| Kokomo, well No. 4 | 936 | 98 | 320 | 332 |
| Marion, well No. 3 | 870 | 78 | 323 | 322.7 |
| Muncie | 900? | (*) | 300? | 286.6 |

* At tide level.

These figures seem to me to settle the question as to the origin of the rock pressure of the gas in this formation. I feel sure that nicer determinations of the facts involved as to altitude and depth would bring a still closer agreement between columns four and five. I will ask you to note in particular the facts as to the St. Mary's and the St. Henry's wells. They have practically the same depth, 1,159 and 1,156 feet; but there is a difference of 38 feet in the depth of the gas rock with reference to sea level. There is a corresponding difference in the rock pressure of 15 pounds, as recorded. The difference in rock pressure due to this 38 feet by calculation is 13.8 pounds, or, practically, 15 pounds. I presume that column five is as near the truth in this particular as column four. The gauge would quite certainly be reported 385 pounds if it lacked but 1 or 2 pounds of that number.

## THE LAWS OF GAS PRODUCTION.

The laws of gas and oil production and accumulation are coming to light more clearly in the flat country of Ohio and Indiana than they have ever done among the hills and valleys of the older Alleghany fields. As it seems to me, no more important deduction from the new

districts has been reached than the law now stated, viz: *The rock pressure of Trenton limestone gas is due to a salt-water column, measured from about 600 feet above tide to the level of the stratum which yields the gas.* The column can be conveniently counted as made up of two parts, viz., a fixed length of 600 feet added to the depth of the gas rock below tide.

If this explanation is accepted as satisfactory for Trenton limestone gas, I venture to suggest that the fact will go a great ways towards rendering probable a like explanation for rock pressure in all other gas fields; but I will not at the present time venture to extend it beyond the limits I have named. I am aware of certain facts, or at least supposed facts, from the older fields that seem difficult of explanation on this basis.

There are a few obvious inferences from this law to which I venture to call your attention in closing this paper:

(1) There is no danger that the great gas reservoirs of to-day will "cave in" or "blow up" after the gas is withdrawn from them. The gas will not leave the porus rock until the salt water obliges it to leave by driving it out and taking its place.

(2) This doctrine lays the ax at the root of all the optimistic theories which blossom out in every district where natural gas is discovered, and especially among the real-estate operators of each new field, to the effect that nature will not fail to perpetually maintain or perpetually renew the supplies which we find so delightfully adapted to our comfort and service. So far as we are concerned it is certain that nature has done about all that she is going to do in this line. In her great laboratory a thousand years are as a single day.

(3) No doctrine could exert a more healthful influence on the communities that are enjoying the inestimable advantages of the new fuel than this. If it were at once accepted it would add years to the duration of these precious supplies of power. The ignorant and reckless waste that is going on in the new gas fields is lamentable. The worst of it comes from city and village corporations that are bringing the gas within their boundaries to give away to manufacturers whom they can induce on these terms to locate among them. To characterize the use of a million feet of natural gas a day, in a single town, for burning common brick, for example, or in calcining common limestone, there is a good word at hand, viz., *vandalism.*

(4) If this doctrine of the rock pressure of gas is the true one, the geologists who have to deal with the subject and the communities that have found a supply owe it to themselves to keep it prominently before the people who are especially interested. They may make themselves temporarily disagreeable thereby, but by just so far as they convince those that are interested, they lengthen the life of these precious supplies.

### THE DURATION OF GAS SUPPLY.

Judging from the present indications, the Trenton limestone gas of Ohio is not likely to be long-lived. It seems entirely probable that the term of its further duration can be stated within the limits of numbers that are expressed by a single digit. In considerable sections of the field, the salt water is very aggressive. It requires a steadily increasing pressure on the wells to hold it back. In one district last year, one hundred and twenty-five pounds pressure would keep the gas dry, while now two hundred pounds are required for the same purpose.

There is likely to be great disappointment in regard to what is called gas territory. The pressure and volume of large areas are found to fail together. Wells draw their supplies from long distances. A farm, or even a mile-square section, may be effectually drained of its gas without a well being drilled upon it.

Natural gas is a very admirable product, but its highest office, after all, should be to prepare the way for something better than itself, viz., artificial gaseous fuel—better, for the reason that while it furnishes all the intrinsic advantages of natural gas, it will be free from the inevitable disadvantages of treasures secured in the way in which the stores of the great gas fields have been gained.

# GEYSERS.

By Walter Harvey Weed.

The hot-water fountains, called geysers, are natural wonders that are of general as well as scientific interest. The striking manifestation which they afford of the earth's internal heat, their great beauty, and novel surroundings make them indeed worthy of that wide-spread interest which they arouse, and it is in the hope of gratifying a general curiosity concerning these wonderful fountains that the present paper has been written.

At the outset of this inquiry into the nature and occurrence of these natural steam engines it is necessary to exactly define what is a geyser? Briefly, a geyser is a hot spring which intermittently ejects a column of boiling water and steam. Before attempting to present such a general account of the various geyser regions of the world as will enable the reader to follow the deductions derived from a study of the occurrence and the characteristics of geysers, it may be well to present a summary of the paper.

It is believed that the facts recorded in this article show:

First. That geysers occur only in volcanic regions, and in acid volcanic rocks. In Iceland and New Zealand the volcanic fires are still active. In the Yellowstone region the lavas are chiefly of pre-glacial age.

Second. Geysers occur only along lines of drainage, on shores of lakes or other situations where meteoric waters would naturally seek the surface. Unheated waters are often found issuing in close proximity to geysers.

Third. Geyser waters are meteoric waters which have not penetrated to great depths but have been heated by ascending vapors.

Fourth. The supply of heat is derived from great masses of lava slowly cooling from a state of former incandescence, heating waters, which, descending to the hot rocks, ascend as highly heated vapors.

Fifth. The intermittent spouting of geysers is due to the gradual heating of water accumulated in fissures or tubes in the rocks, the only mechanism necessary being a tube, which may or may not have local expansions or chambers.

Sixth. Geysers may originate in several ways, though most commonly produced by the opening of new waterways along fissure planes of the rocks, by a gradual eating out of a tube by ascending hot vapors.

Seventh. The thermal activity of geyser regions is not rapidly dying out. The decrease of heat is very slow, and though changes take place from year to year, the establishment of new geysers and new hot springs offsets the decay or drying up of old vents.

Attempts to solve the mysterious spouting of geysers date back to the earlier part of the present epoch of scientific research, and the genius of Bunsen and Deseloiseaux was devoted to a study of the Iceland geysers as early as 1847. The most important result of their experiments and observations was a theory of geyser action, now (with slight modifications) generally accepted, but other conclusions have lately been proven by observations made in the Yellowstone Park to be erroneous. Although numerous visits to the geysers of Iceland by later observers led to various ingenious speculations and theories respecting geyser eruptions, the questions of geyser origin and the signifigance of their occurrence and other questions of broader scope were not touched upon.

The discovery of the geysers of New Zealand appears to have awakened interest, more because of the wonderfully beautiful terraced basins about the geysers of Rotomahana than from any appreciation of the opportunity afforded for a study of the geysers themselves, their relations to the geological structure of the country, or their *raison d'être;* and not until the mapping and study of the Yellowstone geyser basins was made by the Hayden survey, was there the slightest attempt to look at the broader questions awaiting solution. In his final report, after giving an account of various theories of geyser action, Dr. Peale discusses very briefly various pecularities of geysers and the supposed influence of atmospheric charges and concludes with a statement of the three conditions he believes to be necessary to the existence of geysers which are essentially confirmed by the long continued study of the Yellowstone region by the writer.

In looking at the distribution of geysers in various parts of the world one is quickly impressed with their great rarity. Hot springs abound in many countries, but boiling springs are characteristic only of regions of recent (that is geologically recent) volcanic activity; it is only in such regions that geysers occur. Until late in this century Iceland was the only land where geysers had been found. Less than forty years ago they were discovered in considerable numbers in New Zealand, and since then a few others have been reported from other parts of the world. The "Geyserland" of the world is undoubtedly, however, the Yellowstone National Park, a region situated in the heart of the Rocky Mountains, at the head waters of the Missouri and Yellowstone, and discovered so late as 1869.

In order to bring before the reader a general idea of the true relation of geyser vents to the surrounding topography and water courses of the districts, a brief description of the three great geyser regions of the world will be attempted. It has been my good fortune to have spent seven summers at the various geyser "basins" of the Yellowstone in connection with my duties as assistant geologist on the U. S. Geological Survey party, under Arnold Hague. The other regions are familiar from a large series of excellent photographs as well as through the descriptions of friends and the writings of other visitors to those countries.

### THE ICELAND GEYSERS.

Iceland is the birthplace of the word geyser. It has been called the land of frost and fire, and indeed in no place are the evidences, nay the very forces themselves, of frost and fire brought so forcibly in contrast. The island is eminently a volcanic region, a central table-land with sharp volcanic peaks, hooded with great Jökuls or glaciers, mantled with perpetual snows, and surrounded by a more or less narrow strip of lowland bordering upon the sea. The evidences of internal fire are unmistakable. Hecla and other volcanoes are occasionally active, and the whole island is covered with lava poured out by the volcanoes, and the source of the heat supplying the geysers is unquestioned.

As would naturally be expected from the combination of water and fire, hot springs are abundant and at a few localities geysers are found. The most noteworthy of these is Haukadal, where The Geyser, Strokr, and a smaller geyser are found. This locality is about 70 miles from Reykiavik, the Iceland metropolis, and is only reached on horseback over beds of clinkers and rough lava fields; a dreary ride so far as scenery goes, but of fresh novelty to visitors from warmer lands. The hot springs are clustered in an area of about 20 acres, at the base of a hill about an eighth of a mile long and 300 feet high, and at the edge of the marshy bottom that stretches out toward the Hvita River. The springs are really at the base of the seaward border of the high ground where the waters that have percolated through the tufas and porous lavas of the higher region would come to the surface. The two geysers, Strokr and The Geyser, issue from mounds of gray or white silica deposited by the hot waters, and the neighboring springs are surrounded by lesser areas of the same material, while on the hillside back of the springs the rock is decomposed by the steam of fumeroles. These two large spouters show two types of geysers. Strokr has a funnel-like pit 36 feet deep and 8 feet across, (see fig. 1, page 174,) expanding into a saucer-like basin. The tube is generally filled to within 6 feet of the top with clear water, which boils furiously, owing to the escape of great bubbles of steam coming from two openings in opposite sides of the

tube. The eruptions are quite as beautiful as those of its more famous companion, the jets rising in a sheaf-like column to a height of 100 or more feet, eruptions taking place at very irregular and long intervals; but by putting a lid on this great kettle, by dumping in large pieces of turf, an eruption can be produced in a short time.

The Geyser, on the contrary, is a pool of limpid, green water whose surface rises and falls in rhythmic pulsations. The usual temperature is but 170° F. or 200° F., but varies, being greater immediately before an eruption. The shallow, saucer-like basin is about 60 feet across and slopes gently to a cylindrical shaft 10 feet in diameter, forming the pipe of the geyser; this is about 70 feet deep. This regularity of the tube becomes important when we consider Bunsen's experiments and the theory of geyser action he deduced from them. Before an eruption bubbles of steam entering the tube suddenly collapse with loud but muffled reports and a disturbance of the quiet surface of the water. During this simmering, for such it is, the water rises in dome-like mounds over the pipe and overflows the basin, running down the terraced slope and wetting the cauliflower-like forms of sinter that adorn it.

The eruptions that so long puzzled and astonished visitors to this remote land are surpassed by those of the giants of the Yellowstone, but their beauty is not less. A short time before Geyser plays, the domes of water rising in the center of the basin, come in quick succession and finally burst into spray, followed by a rapid succession of jets increasing in height until the column is 100 feet high. Dense clouds of steam momentarily hide the glistening sheaf of jets, hiding it from sight, then drifting away in the breeze again reveal the sparkling shaft.

These eruptions have varied much in appearance and height since the geyser was first known. At present the column does not exceed 90 feet and the eruption lasts but a few moments. After it the basin is empty and seems to be lined with a smooth coating of white silica.

## THE GEYSERS OF NEW ZEALAND.

The geysers of New Zealand are situated in a region clothed with a luxuriant vegetation that is in strong contrast to the bleak and barren lava fields of Iceland, but an examination of the position of the springs, with respect to the physical features of the region, shows that the situation of the geysers is nearly the same in these antipodal isles. The New Zealand geysers occur in the North Island, in what is known as the volcanic region, or the Taupo zone. Within an area of 4,725 square miles, in which none but volcanic rocks are found, there are six volcanoes, and great numbers of solfataras, fumeroles, mud volcanoes, and hot springs, and many geysers. The lavas are all of the acid type, mostly rhyolite, but are hidden by surface decomposition and an abundant vegetation, save upon the flanks of the peaks. The axial line of

this zone running northeast is marked at each end by an active volcano, and its course by a line of greatest hydrothermal activity; a sinuous line of hot springs following well marked geographic features of river valleys, low plains, and lake margins, with higher country on either side rising to plateaus of 2,000 to 3,000 feet above the sea.

Little is known of the geysers on the shores of Lake Taupo, or those on the banks of the Waikato River, but the famous terraces of Rotomahana, called the eighth wonder of the world by James Anthony Froude, attracted attention to the geysers which formed them, and made their vicinity the best known part of the district. The warm lake, called by the Maoris, Rotomahana, was a shallow body of warm water, about a mile long, and a quarter of a mile broad, comprising 185 acres. The waters were of a dirty, greenish hue, reflecting the somber green of the fern and the ti-tree-covered slopes about it, and the sedgy margins sheltered large numbers of duck and other waterfowl. Rising above its surface like stairways of delicately sculptured marble, were the pink and white terraces. At the top of the terrace, 120 feet above the lake, was the Terata geyser, whose overflow had built up this wonderful work and filled the basins and pools with waters whose tints were both the delight of the eye and the despair of the pen.

The geyser caldron was some 60 by 80 feet across, its clear and boiling water usually overflowing, and occasionally ejected to a height of 40 to 100 feet, wetting the steep banks of bright-colored fumerole clays about the crater, but not forming the beaded geyserite, characteristic of so many of these fountains. Such eruptions followed a period of quiescence, when the waters retired within the pipe for many hours. Owing to the comparative inaccessibility of the caldron and the beauty of the terraces, but few observations are on record of the action of the geyser. The water carried 150 grains of solid matter to the gallon, of which one-third was silica, and the daily outflow of 100,000 to 600,000 gallons per hour brought up 10 tons of solid matter dissolved out of the underlying rocks. It is easy to see what great underground caverns would be formed by this geyser alone in a comparatively brief time. In the volcanic outbreak of Tarawera, in June, 1886, the waters of the lake and underground reservoirs were drawn into the newly opened fissure, and, by the extraordinary explosion that followed the terraces were destroyed, and the site of Rotomahara became a crater that threw mud over the surrounding country.

### THE YELLOWSTONE "GEYSERLAND."

The wonderful variety, the great number, and the large size of the geysers of America, found in the Yellowstone National Park, demand a somewhat longer account of this region, which I am the more willing to give as it has been my good fortune to have spent a large part of

the past nine summers in a study of its geysers and hot springs. To many readers this region is doubtless familiar. The geysers are found in detached groups, occupying basins or valleys of the great table-land which forms the central portion of the park, a region whose heavy forests and uninviting aspect, combined with the rugged nature of the encircling mountain ranges, so long proved a barrier to exploration even to those adventurous trappers and prospectors of the Great West, and deferred the discovery of this marvellous region until so recent a date as 1869.

The geyser "basins," as the localities are termed, conform, in their relations to the surrounding high ground and their coincidence with lines of drainage and the loci of springs, to the laws governing the distribution of the same phenomena in other parts of the world. The park itself is a reservation of about 3,500 square miles, the central portion being an elevated volcanic plateau, accentuated by deep and narrow cañons and broad gentle eminences, and surrounded by high and rugged mountain ranges. This central portion, whose average elevation is about 8,000 feet above the sea, embraces all the hot-spring and geyser areas of the park. The volcanic activity that resulted in the formation of the park plateau may be considered as extinct, nor are there any evidences of fresh lava flows. Yet, the hot springs so widely distributed over the plateau are convincing evidence of the presence of underground heat. There is no doubt that the waters derive their high temperature from the heated rocks below, and that the origin of the heat is, in some way, associated with the source of volcanic energy.

The various geyser basins, or *fire holes*, as they were called by the first explorers, each possess individual peculiarities which give character and interest to each locality. The most noted of these "basins" is however that known as the Upper Geyser Basin of the Firehole River, one of the headwaters of the great Missouri. This "Upper Basin," as it is generally called, lies a little westward of the center of the park, and is reached by a ride of some 50 miles, over excellent roads, from the railroad terminus. It is a valley of 1½ miles long by one-half mile broad, inclosed by the rocky cliffs or darkly wooded slopes of the great Madison Plateau, and drained by the Firehole River, along whose banks the largest geysers are situated. The whole floor of the valley is fairly riddled with springs of boiling water, whose exquisite beauty is indescribable. Light clouds of fleecy vapor curl gently upward from waters of the purest azure or the clearest of emerald, and, encircling rims of white marble-like silica, form fit setting for such great gems. A large part of the valley floor is covered with the white deposit of silica known as siliceous sinter, deposited by the overflowing hot waters.* The weird whiteness of these areas, the gaunt white trunks of pine trees killed by the hot waters, the myriad pools of steaming crystal, and the

* See "Formation of Hot Spring deposits," W. H. Weed *Ninth Ann. Rept. Director U. S. Geological Survey, 1889.*

white clouds floating off from the chimney-like geyser cones, form a scene never to be forgotten by those fortunate enough to behold it. Within this basin there are nearly thirty geysers, presenting many variations of bowl or basin, mound and cone, and whose eruptions are equally diversified in form and beauty.

Sentinel, Fan, Cascade, Riverside, Mortar, and Grotto, greet one on entering the basin, either by quiet steaming or by flashing jets. Giant, Splendid, Castle, Grand, Giantess, Lion, and Old Faithful are but a few of the wondrous fountains of the place. The last is most deserving of its name. Every since its discovery, in 1870, it has not failed to send up a graceful shower of jets at a regular interval of sixty-five minutes. Its beauty is ever varying, as wind and sunlight play upon it, and the mound about its vent is adorned with delicately tinted basins of salmon, pink, and yellow, filled with limpid water whose softness is enticing. It is the geyser of the park, and indeed of the world, and many a visitor to "geyserland" departs without seeing any other of the many spouters in action and yet feels more than repaid for the journey. For beauty of surroundings, the Castle will perhaps be awarded the palm; its sinter chimney or cone is formed of exquisite cauliflower or coral-like geyserite whose general form makes the geyser's name appropriate. Its eruptions are frequent, occurring about every thirty hours, when a stream of hot water is thrown up to a height of 75 feet for some fifteen minutes, followed by the emission of steam, with a loud roar that can be heard for miles. A few hours after the eruption the tube is again full, and occasional jets of 10 to 20 feet are thrown out until the next eruption ensues.

The greatest geyser of the park, and, indeed the grandest of the whole world, is Excelsior, some 25 miles beyond the Norris Basin. Unlike the less capricious and more fountain-like geysers of the Upper Firehole, this monster of geysers does not spout from a fissure in the rock, nor from a crater or cone of its own building. It is a monster of destruction, having torn out its great crater in the old sinter-covered slope, builded by the placid and beauteous Prismatic Lake. The walls, formed by the jagged ends of the white sinter layers, are lashed by the angry waters that are ever undermining the sides and enlarging the caldron. The eruptions are so stupendous that all other geysers are dwarfed by comparison. The grand outburst is preceded by several abortive attempts, when great domes of water rise in the center and burst into splashing masses 10 to 15 feet high, while the waters surge under the overhanging walls and overflow the slope between the crater and the river. Finally, with a grand boom or report that shakes the ground, an immense fan-shaped mass of water is thrown up to a height of 200 or more feet, great clouds of steam rolling off from the boiling water, while large blocks of the white sinter are flung far above the water and fall about the neighboring slopes. It is a sight that inspires enthusiasm in the most phlegmatic, and few can resist the temptation

to give loud expression to their feelings. Unfortunately, this monarch of all geysers has ceased to erupt, but may be expected to break forth again at any time.

Everywhere save at the Norris basin, of the Yellowstone Park, geyser vents are surrounded by cones, mounds, or platforms of white siliceous sinter, which, though built up into very beautiful forms, hides the true relation of the geyser vent to the fissures in the rocks, so that it has been generally believed, as stated by Tyndall,* that the hot springs built up tubes of siliceous rock, that made them geysers. That this is not true is shown by several great fountains at the Norris basin, that, spout directly from fissures in the solid rock, notably the Monarch, Tippecanoe, and Alcove geysers.

## GEYSER WATERS.

The descriptions which have been given of the chief geyser regions of the world lead to the question: What is the source and character of the geyser waters? It has been plainly indicated that, in the fields described, the vents are always situated along lines of drainage, on the shores of lakes, or under conditions where ordinary springs of meteoric water would naturally occur.

That the geyser waters are surface waters which have percolated through the porous lavas and have been heated by encountering great quantities of steam and gases rising from the hot rocks below there is no reasonable doubt. The proximity of ordinary cold springs and those of boiling hot water lends support to this view.

These hot waters, traversing the rocks in irregular fissures, readily dissolve out the more soluble constituents of the rocks, the amount and the character of the salts present varying somewhat with the nature and amount of gases held in the waters. Chemical analyses of geyser waters from the three regions described show no greater variation than those from different vents in any one of these regions. The following table of analyses shows that the waters are all similar in character. The analysis of the Yellowstone water was made by Prof. F. A. Gooch and for the U. S. Geological Survey. Analyses are also given of the water from the great geyser of Iceland, and from the New Zealand geysers, the former by Damour,† the latter by Smith.‡

* Heat as a mode of motion.

† *Ann. Chem. u. Pharm.*, vol. LXII, 1847, p. 49.

‡ *Jour. für prakt. Chemie.*, vol. LXXIX, 1869, p. 186.

*Analyses of geyser waters.*

[Constituents grouped in probable combination. Grams per kilogram.]

| | Old Faithful Geyser. | Great Geyser, Iceland. | White Terrace Geyser, New Zealand. |
|---|---|---|---|
| $SiO_2$, silica | 0.3961 | 0.5190 | 0.6060 |
| $NaCl$, sodium chloride | 0.6393 | 0.2379 | 1.6220 |
| $LiCl$, lithium chloride | 0.0340 | ........... | *0.0950 |
| $KCl$, potassium chloride | 0.0478 | ........... | ........... |
| $KB$, potassium bromide | 0.0051 | ........... | ........... |
| $Na_2SO_4$, sodium sulphate | 0.0270 | 0.1342 | ........... |
| $Na_2B_4O_7$, sodium borate | 9.0213 | ........... | ........... |
| $Na_2AsO_3$, sodium arseniate | 0.0027 | ........... | ........... |
| $Na_2SiO_3$, sodium silicate | 0.0279 | ........... | †0.2290 |
| $Na_2CO_3$, sodium carbonate | 0.2088 | 0.2567 | ........... |
| $MgCO_3$, magnesium carbonate | 0.0021 | ........... | Trace. |
| $CaCo_3$, lime carbonate | 0.0038 | ........... | 0.025 |
| $FeCO_3$, iron carbonate | Trace. | ........... | ........... |
| $Al_2O_3$, alumina | 0.0017 | ........... | 0.005 |
| $H_2S$, hydrogen sulphide | 0.0002 | ........... | ........... |
| $NH_4Cl$, ammonium chloride | Trace. | ........... | ........... |
| $CO_2$, carbonic acid | ........... | ........... | ........... |
| $K_2SO_4$, potassium sulphate | ........... | 0.0180 | 0.0750 |
| $MgSO_4$, magnesium sulphate | ........... | 0.0091 | ........... |
| $Na_2S$, sodium sulphide | ........... | 0.0088 | ........... |
| Total | 1.3908 | 1.2305 | 2.6570 |
| Specific gravity | 1.00096 | 1.000205 | 1.00077 |

* $CaCl_2$. † $Na_2O$.

*Source of heat.*—That the source of steam is the still hot lavas below, and is in some way connected with volcanic action, is so evident from the facts that no other conclusion is possible. A very common belief concerning the source of the heat of boiling springs and geysers, but one which no longer has the support of scientific men, is that the heat results from *chemical action*, as it is vaguely termed. Were not the evidence so directly opposed to this idea, it would merit consideration, but so far as the heat of geyser waters is concerned, all observation shows it to be untenable. To this class of theories belongs the popular idea that the geyser basins are underlaid by great beds of (quick?) lime, which supply the heat and steam of the geysers.

The smothered combustion of beds of lignite, coal, or pyrites, is another form of the same theory that has been received with considerable favor, and still commands a few followers. That hot springs may have such an origin is not denied, but the geological conditions and environment clearly show that none of the great geyser regions of the world derive their heat from such action.

Where the source of supply is deep-seated, spring waters always have an elevated temperature, generally proportionate to the depth, but the very high temperatures of the geysers and the local source of

the waters excludes this theory. The folding and faulting of rocks is another source of heat made manifest by hot springs.

It has been shown by Dr. Peale, however, that *boiling* waters are only found in the regions of volcanic rocks, and it was pointed out by L'Apparent that geysers only occur in acid volcanic lavas. In Iceland the volcanic forces are still active, and melted lavas may exist at no great depth. In New Zealand the recent eruption of the eroded mountain Tarawera showed that heated rocks exist, and in that case rose up near enough to the surface to cause the explosion which so transformed the country.

In the Yellowstone there are no active volcanoes, and none of even geologically recent activity. The lavas that fill the ancient mountain-encircled basin of the park are scored by glaciers and deeply cut by running water; and the old volcanoes from which the lavas were, in part at least, outpoured show no signs of having been active since Tertiary times. Yet in this region the expenditure of heat by the hot springs, geysers, and steam vents would undoubtedly keep a moderate-sized volcano in a very active state were it concentrated. There is no doubt that this heat is connected with the past volcanic energies of the region and derived principally from the still hot lavas, three-quarters of the entire area of the park (3,500 square miles) being covered by rhyolitic rocks.

The significance alluded to above, of the association of geysers and acid lavas (rhyolites), is possibly to be found in the fact that these rocks are more easily dissolved by the hot waters forming the tubes and reservoirs for geysers. The situation of hot springs and geysers along water courses has already been mentioned. It is a well-known fact that the presence of water in the pores of a rock increases its capacity to conduct heat, so that we may surmise a rise in the local isogeotherm in such situations.

*Geyser eruptions.*—Geysers have often been compared to volcanoes, presenting in miniature, with water instead of molten rock, all the phenomena of a volcanic eruption. The diversity of form and varying conditions of activity of the hot springs found associated with geysers makes it impossible to determine in every case whether a spring is or is not a geyser. Geyser vents may be mere rifts in the naked rocks or bowls of clear and tranquil water, quiet until disturbed by the first throes of an eruption, and surrounded by white sinter deposits in nowise distinguishable from those about hot springs. In other cases the vents are surrounded by a cone or mound of pearly-beaded "geyserite," a certain and distinctive feature of a geyser.

The displays of the great "Geyser" of Iceland have already been briefly described; they may be taken as the type of eruptions from geysers having bowl-like expansions at the top of the tube, the so-called "basin" of the geyser. Where the vent is surrounded by a cone of sinter, as is so often the case among the fountains of New Zealand and

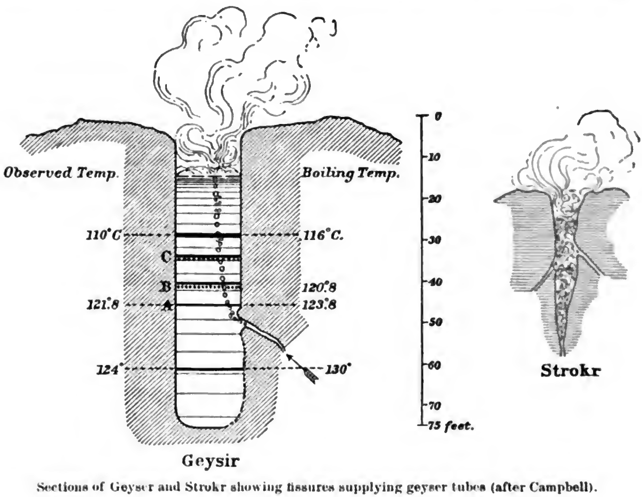
the Yellowstone, the first part of the geyser eruption is somewhat different. Perhaps the most familiar geyser of this type is Old Faithful, the one geyser in the Yellowstone that is sure not to disappoint the visitor. Though surpassed by many of its neighbors in the height and magnitude of its eruptions, it holds a front rank for beauty and gracefulness. Previously heralded by loud rumblings, with spasmodic outbursts of 10 to 20 feet in height that mark abortive attempts to send up its steaming pillar, the white column is finally thrown upwards with a loud roar, and mounts at once to a height that seems hundreds of feet as we gaze upon it. For two, or even three minutes, the column maintains a height which measurements show to vary from 90 feet up to 150 feet, with occasional steeple-shaped jets rising still higher, the jets ever varying and giving off great rolling clouds of steam; then the jets gradually decrease in altitude, and in five minutes the eruption is over, the tube apparently empty, and emitting occasional puffs of steam for a few minutes longer.

During the eruption the water falls in heavy masses about the vent, filling the basins that adorn the mound, and flowing off in yellow and orange-colored waterways, while the finer spray drifts off with the breeze and falls upon the neighboring sinter slopes. It is impossible to measure the amount of water thrown out, since it runs off in a number of directions in shallow rills that lead either to the sandy terrace near by or to the river. If however we assume that the column of steam and water is one-third water, a fair assumption, the estimated discharge is 3,000 barrels at each eruption.

Comparing Old Faithful with its Iceland prototype we find considerable difference in the behavior of the two vents during the interval between eruptions. The former, like Strokr, has no bowl or basin, and the geyser throat or tube is partly filled with water, which is in constant and energetic ebullition, while the geyser is inactive. The tube and bowl of "Geyser" are, on the contrary, filled with comparatively cool water. In each case, however, the eruption is preceded by an overflow from the geyser tube, in the case of Strokr and Old Faithful, as jets of 10 feet to 25 feet in height; in "Geyser" by a filling of the bowl and successive overflows, accompanied by the noise of condensing steam bubbles, a simmering of the water in the tube. Such preliminary actions are significant when we consider the theory of geyser action.

*Theories of geyser action.*—The intermittent spouting of geysers was long a riddle to scientific men, for although several theories seemed each to offer a satisfactory explanation of the eruptions of "Geyser," they supposed conditions unlikely to occur in many vents. The investigations of Bunsen, and of Descloizeaux, who spent two weeks studying the Iceland fountains, resulted in the announcement of a theory of geyser action which, with slight modifications, has satisfied all requirements and is to-day generally accepted as the true explana-

tion of the action of these natural steam engines. This theory, which bears the name of the illustrious Bunsen, depends upon the well-known fact that the boiling point of water rises with the pressure, and is therefore higher at the bottom of a tube of water than at the surface. The temperature of water heated in any vessel is generally equalized by convective currents, but in a long and narrow or an irregular tube this circulation is impeded, and while the water at the surface boils at 100° C. (at sea level), ebullition in the lower part of the tube is only possible at a much higher temperature, owing to the weight of the water column above it. In the section of Geyser shown in the figure the observed temperatures are given on the left, and the temperatures at which the waters would boil, taking into account the pressure of the water column, are given on the right. In Geyser the nearest approximate to the boiling point is at a depth of 45 feet oppo-




Sections of Geyser and Strokr showing fissures supplying geyser tubes (after Campbell).

site a ledge and fissure discovered subsequent to Bunsen's experiments. At this depth the temperature is 2° C. below the temperature at which the water can boil. If by the continued heating of this layer by steam from the fissure it attains the temperature at which it can boil, steam is formed, whose expansive force lifts the superincumbent column of water, causing a slight overflow at the top, which, shortening the column, brings the layer B to the position C, where its temperature is above the boiling point of C, wherefore steam is formed at this point and a further lifting and relief of pressure ensues, followed by an eruption.

In illustration of this theory a model geyser is easily constructed of a glass tube of an inch or so in diameter and several feet long. When

this tube is closed at one end, filled with water and placed upright we have all the mechanism necessary to produce all the phenomena of a geyser. By heating the water at the bottom by the introduction of steam (or with a spirit lamp), we can produce eruptions whose period will depend upon the intensity of the heat. At first the bubbles of steam collapse in the cool waters at the bottom of the tube, but as the temperature rises the bubbles rise part way up the tube and heat the lower part of the column to a high temperature while the water near the surface is still cool. Eventually the water at the bottom reaches the pressure boiling point, when steam is formed, lifting the water above it and causing an overflow at the top. This overflow or its equivalent, the filling of a shallow basin at the top of the tube, relieves the pressure and all that part of the column whose temperature was previously below the boiling point but now exceeds it, flies into steam and ejects the water above with great violence. The glass walls of our geyser tube permit us to watch the gradual heating of the water by means of thermometers suspended in the tube, the ascent and collapse of steam bubbles, the overflow and abortive attempts to erupt and the final ejection of the water from the tube.

Where the tube is surrounded at the top by a basin no actual overflow need occur. Indeed there is in the Yellowstone a miniature geyser, aptly named the Model, with a tube but 2 inches in diameter, surrounded by a shallow, saucer-like basin, which has eruptions about every fifteen minutes of 3 feet to 5 feet in height in which scarcely a drop of water is wasted, but flows back into the tube after the eruption. During the interval between eruptions no water can be seen in the tube, whose basin and upper part are dry and cool. The first signal of the coming display is a quiet welling up of the water in the tube filling the little basin, which being relatively large and shallow relieves the water column of a considerable height. During the eruption which follows, the spray is chilled by the air, falling back into the basin; at the end of the display the water is quickly sucked back into the tube and re-heated for the ensuing eruption.

At first thought the constant boiling of the waters in the tube of Strokr, Old Faithful and many other geysers seems to oppose the theory which we have just given. Observations show however that in many cases the boiling is confined to the surface and deep temperatures do not reach the boiling point corresponding to the depth. It is quite likely also that in some cases a lesser and independent supply of heat may connect with the upper part of a geyser tube; Strokr, we know, has two vents (see figure), one of which is the geyser tube, the funnel-like throat of Strokr being really but a nozzle to the geyser.

It is unnecessary to describe the numerous other theories of geyser action; they all suppose caverns or systems of chambers and tubes, of definite arrangement, a supposition most unlikely to occur in many cases, and made unnecessary by Bunsen's theory. Local expansions and irregularities of the tube do exist, and to them we owe many of

the individual peculiarities of geysers, but such chambers do not form a vital, essential part of the geyser mechanism.

In an excellent *résumé* of the various theories of geyser action, Dr. A. C. Peale states that he believes no one theory is adequate to explain all the phenomena of geyser action, though Bunsen's theory comes nearest to it. *

I believe however that Bunsen's theory is a perfect explanation if we but admit that the geyser tube may be neither straight nor regular, but of any shape or size, and probably differing very much for each vent. The shape of the bowl or basin exercises but little influence upon the eruption save to produce the many individual peculiarities of the geyser column.

*Origin of Geysers.*—It should be noted that Bunsen's theory of geyser action is quite independent of his theory of geyser formation. The building up of a siliceous tube by the evaporation of the waters at the margin of a hot spring, is a process which may be seen in operation in any of the geyser regions of the world; but it is not a necessary prelude to the formation of a geyser, for a simple fissure in the rock answers equally well, as is shown at the Norris geyser basin in the Yellowstone Park.

The life history of a geyser varies, of course, for each one, but observations show that the following sequence of events often takes place. The hot vapors rising from unknown depths penetrate the rocks along planes of fracture and shrinkage cracks, decomposing and softening the rock until the pressure of the steam and water is sufficient to force an opening to the surface. If this opening affords an easier exit for waters issuing at a higher level the fissure is probably opened with a violent ejection of mud and débris; more often the process is a gradual one, accompanying the slow eating away of the rock walls along the fissure. The flowing waters slowly clear out the fissure, forming a tube that permits the freer escape of hot water and steam, while at the same time the waters change from a thick mud to a more or less clear fluid. The spring, at first a simple boiling mud-hole, is now an intermittently boiling spring, which soon develops true geyser action. If the opening of the fissure afforded a new outlet for the waters of some already existing geyser, these changes take place rapidly, and eruptions begin as soon as the pipe is sufficiently cleared to hold enough water. The bare rock about the vent or fissure is soon whitened by silica deposited by the hot waters. This *sinter* may form a mound about the expanded tube or basin, or, if the vent be small and spray is frequently ejected, it builds up the curious geyser cones so prominent in the Yellowstone. In certain cases the building up of these deposits may partially choke the geyser's throat, and cause a diminution of the geyser's energy, whose forces seek an easier outlet. In other cases the eating out of new subterranean waterways deprives the geyser of its supply of heat,

* *Twelfth Ann. Rept. U. S. Geol. and Geog. Survey Territories*, vol. II., p. 422.

and the vent becomes either a tranquil *laug* or wholly extinct, while the pearly *geyserite* forming its cone disintegrates and crumbles into fine shaly débris, resembling comminuted oyster shells. Thus there is a slow but continual change in progress at the geyser basins, in which old springs become extinct and new ones come into being and activity.

With few exceptions, where the vents are very new, geysers spout from basins or from cones of white siliceous sinter, or *geyserite*, deposited about the vent by the hot waters. Such deposits are formed very slowly, one-twentieth of an inch a year being an average rate of growth for the deposit formed by evaporation alone. These deposits of sinter are therefore an index to the age of the geyser. In many cases these sinter cones are very odd, fantastic structures of great beauty while wet by the the geyser spray, but becoming white, opaque, and chalk-like upon drying. Where the spattered drops fall in a fine spray the deposit is pearly, and the surface very finely spicular. If the spray be coarse the rods are stouter and capped by pearly heads of lustrous brilliancy. Thus the cone is not only a measure of a geyser's age and activity, but it tells, in a way, the nature of the eruption.

*Artificial production of geyser eruptions.*—Eruptions of Strokr have, for many years, been provoked by artificial means. The funnel-shaped geyser throat makes it an easy matter to plug it with a barrowful of turf cut in the adjacent marsh. This acts as a cover, confining the steam, which finally overcomes the resistance and produces an eruption. Travellers have also attempted to hasten the eruptions of geysers by throwing blocks of sinter down the tube, but it is evident that such measures can only succeed when the forces of heat and pressure are in a very delicate equilibrium.

In the Yellowstone geyser basins it has been found that geyser eruptions may be hastened or even caused in simply boiling springs by the use of soap or of lye. The discovery of this extraordinary fact was made in a very curious way. A Chinaman was engaged by the hotel company to wash the soiled linen; thinking to utilize the abundance of hot water provided by nature, a rude canvas building was put up over a small, circular, boiling spring near the edge of the Firehole River. In this spring the partly cleansed and soaped clothes were put to boil, suspended in a wicker-basket. All went well until the Chinaman left his bar of soap with the clothes, when the spring suddenly threw out basket, clothes, and hot water, wrecking the shanty and starting the Chinaman on a run from a place that was too near the infernal regions for comfort. This eruption, and the observed effect of soap in increasing the ebullition of boiling springs, led to the use of soap to produce eruptions of this boiling but not spouting spring, thenceforth known as the Chinaman.

The success attending the use of soap in this instance suggested to a photographer, F. Jay Haynes, the use of soap, or its equivalent, lye, to hasten eruptions of those geysers of which he desired to obtain

photographs, and led to experiments by the Geological Survey* showing that eruptions can be produced in many cases of geysers, which have been most capricious in their exhibitions, or have been inactive for weeks or even months. The conditions essential to the successful use of soap or lye for this purpose seem to be that the geyser tube be small, and the water near its boiling point, if not actually boiling at the surface. Many of the bowls in the Yellowstone possess a temperature at their surface exceeding the theoretical boiling point for the altitude by 1 or 2 degrees. This apparently anomalous fact is not due to the mineral matter held in solution by the hot waters, for the analyses show that amount to be too small to have any appreciable effect, but it is explained by the waters being free from air, it being well known to physicists that water freed from air has an increased boiling point, because of the greater cohesion of the particles. The effect of the soap is to increase the viscosity of the water, the consequent explosive liberation of steam producing an eruption.

*Variations in geyser periods.*—Many geysers are easily mistaken for simple hot or boiling springs, since during the long intervals between eruptions they present no indications of their true nature.

The interval between eruptions is manifestly dependent upon the two factors of heat and water supply. It rarely happens that these factors are so constant that the geyser has a definite period. Even in the case of Old Faithful, the most reliable of all geysers, there are very considerable variations in the period, though the average is always constant from day to day.

It sometimes happens that a slight change in the conditions—a lessened amount of heat or increased amount of water—will cause a cessation of a geyser's eruptions for a long period. This has happened in New Zealand, where the Waikite geyser, near Lake Rotorua, inactive for many years, suddenly exploded, scattering blocks of sinter and scalding several Maoris who happened to be near by. The Excelsior, undoubtedly the largest geyser of the world, was not seen in action until 1878, continuing its periodic eruptions till 1882, when it ceased and did not play again until 1888. Last summer it was again inactive, though the water boiled furiously, bulging up several feet in the center of the great caldron.

Observations made in New Zealand have led to the belief that the eruptions of certain geysers were influenced by the barometric pressure, and it is said that certain geysers are only active during the prevalence of a northwest wind. Observations in the Yellowstone show no such correspondence. As a rule the water surface exposed is small and the effect of temperature and pressure would be scarcely appreciable, yet theoretically it is quite probable that when the forces in a geyser are in a delicate equilibrium a change of temperature and pressure of the air would be quite sufficient to cause an eruption.

* "Soaping Geysers," Arnold Hague. [*Trans. Am. Inst. Min. Eng.*, Feb., 1889.]

# ON THE GENERAL CIRCULATION OF THE ATMOSPHERE.*

By WERNER VON SIEMENS.

Translated from the German, by GEORGE Edward CURTIS.

In an article in the May number of the *Meteorologische Zeitschrift* entitled "On the theories of the general circulation of the atmosphere, etc.," Mr. A. Sprung has published a criticism of my computation of the direction and force of the general atmospheric current contained in my memoir, entitled "On the conservation of energy in the earth's atmosphere," presented to the academy March 4, 1886. These criticisms induce me to make a brief reply, not, indeed, for the purpose of rebutting the objections of Dr. Sprung to the rigid validity of the results of my computation—objections with which in part I wholly agree—but to answer the assumption that I have made the attempt, in the same way as Ferrel, "to build up on theoretical computations a theory of the general circulation of the atmosphere." Setting aside the fact that I do not consider myself to be sufficiently versed in mathematical analysis for such an attempt, I hold that this method is utterly inappropriate. A problem so extraordinarily complicated as that of the general circulation of the air can not possibly be constructed backwards upon the basis of mathematical computations. There has been lacking up to the present time the simple fundamental law governing all the phenomena in action. In my considerations "Upon the conservation of energy in the earth's atmosphere," I have endeavored first to state the forces which produce, maintain, and retard atmospheric motions, and next I have sought to determine by computation the general motion of the air, both in direction and magnitude, produced by their interaction. With respect to this method, it is not correct to say that I, "in the same way as Ferrel before me, would show by computation an original condition of motion in the atmosphere," in order to make it a basis for my further speculations. It is equally incorrect to say that in my computations I have wholly neglected the retardation of the motion of the air by friction.

The meridional air current, very aptly called by Sprung the fundamental circulation (*Grundcirculation*), upon which my theory of the

* From the *Sitzungsberichte der Königl. Préuss. Acad. der Wiss.* zu Berlin.

general system of winds is based, depends, in plain terms, on the equilibrium between the acceleration of the air in the equatorial updraft (caused by the overheating of the lowest air layers of the torrid zone by solar radiation) and the loss of energy which the transported air experiences in its course. The mixture of the air masses, which, without a "fundamental circulation," must rotate with the velocity of the earth's surface upon which they rest, is accomplished by it in the course of a thousand years. I have used the mathematical idea of the sudden frictionless mingling of air layers at all latitudes only in order to determine in a simple way the condition of motion both with respect to direction and magnitude already prevailing since a primitive period. Ferrel does not proceed, as I do, from a fundamental circulation which inter-changes the air layers rotating with their respective latitude velocities while moving forward and thereby gradually mixes them, but allows this mingling to be effected in a meridional direction by a frictionless displacement of the rotating rings of air at different latitudes, the reasons for which are not specifically given. This conception of the mode of mixture furnishes essentially the same basis for computation as mine, and Ferrel reaches the same results of computation so far as the direction of the wind currents is concerned. But, on the other hand, there exists an essential difference in our results for the relative meridional wind force at the latitude of 35°.

The assumption of Dr. Sprung that neither of the two theories can be regarded as completely correct I wholly agree with. In fact I have never considered my theory in any other light than as a first approximation to the truth. With this idea I have left out of consideration in my computation complicated influences, such as that of the decrease of temperature toward the poles and that of the non-coincidence of the direction of the centrifugal force with the force of gravity. The latter fact, whose action is also left out of consideration, that rotating air masses in higher latitudes must everywhere have the tendency to move forward in great circles, and thus tend to move toward the equator, would cause a decrease of air pressure as we approach the poles, and would consequently essentially impair the result of my computation of the mixing, if this tendency were not compensated by other forces which have an opposite effect. It is not these, however, but other assumptions of a fundamental character which mark a very essential difference between the two conceptions and lead to results quite at variance with one another. In the first place, I refer to Ferrel's assumption that the so-called principle of areas, in the form of the conservation of the moment of rotation, applies to the displacement northward or southward of the air rotating with the earth's surface. I can not agree with this, and must enter my decided protest against the idea that the conservation of the moment of rotation is applicable to the movement of the air.

The law of areas, borrowed from astronomy, means that a mass which moves freely around another describes equal areas in equal

times. This happens in consequence of the acceleration of the rotating mass while approaching the center of attraction of the fixed mass, and the corresponding retardation which it experiences in departing from it. The greater velocity derived from the acceleration results in the description of a greater arc in a unit of time, and leads therefore to the laws of areas. Now, according to Ferrel, a mass of air rotating with the earth's surface in any latitude, when displaced northward or southward, can not, as I understand it, continue its course with its absolute velocity unchanged, as would be the case in the conservation of its *vis viva*, but its moment of rotation must remain constant, which corresponds to an important change of velocity. In order that the moment of rotation shall remain constant—which will be the case if the linear velocity of the rotating body changes in such a way that equal surfaces are described by it in equal times—there must be expended a considerable amount of energy in order to effect the change of velocity of the inert mass. But the force that could do this work is quite lacking. If we shorten the radius of rotation of a rotating solid mass, then the force which causes the shortening must overcome the centrifugal force. The sum of the products of all the centrifugal forces overcome by the paths traversed gives the work performed in accelerating the rotating mass, and this is sufficient to maintain the law of surfaces; that is, here the moment of rotation is constant. But in the motion of the air upon the earth's surface, no analogous relations subsist. In a tangential displacement on the earth's surface, no change of gravity takes place and no acceleration of the displaced mass by gravity. It is just as difficult to understand by what means a pressure upon them of neighboring air layers should arise for displacing, which would be able to do the enormous work of acceleration that the conservation of the moment of rotation requires!

A displacement of the whole air mass of a rotating ring in a north or south direction is not practicable, since the volume of such a ring of given thickness changes with the cosine of the latitude. Thus in a poleward displacement, a corresponding part of the mass of the ring must remain behind—relatively, must return to the equator. But also for the portion of the ring of air actually displaced toward the pole, no physical reason can be found why the conservation of its moment of rotation must be assumed. On the contrary, this assumption would lead to the greatest contradictions and discontinuities; for, in the assumed original condition in which no meridional currents yet existed, from which Ferrel as well as I have proceeded, the air rotated at each latitude with the velocity of the ground upon which it was at rest. The velocity of the masses of air therefore decreased with the cosine of the latitude Now, with the appearance of a meridional current, this relation, according to Ferrel, would not only have to be inverted, but instead of a decrease, an increase in the velocity of the air must take place at a still higher rate, if the moment of rotation of the air is to

remain constant. But why this must remain constant and what force could effect the enormous increment of the *vis viva* stored up in the rotary air mass, remain equally incomprehensible.*

I pass now to another assumption of Ferrel's, with which I cannot bring myself to agree. It is this, *i.e.*, that on an inclined surface of equal air pressure there can be a descent of the overlying air layers. It is just as impossible that there should be an impulse to tangential displacement on sloping isobaric surfaces as in the case of level surfaces. That such a displacement could not possibly exist is evident at once from the consideration that a descending stream of air, in case it actually begins at any time, must immediately develop a change of pressure destroying the equilibrium, and must at once produce a return current. It results from this that a continuously progressive heating of the atmosphere, such as in reality (aside from disturbances) takes place from the polar regions down to the equator, furnishes no possibility for a meridional circulation such as Dove also has assumed. It is possible, in such an unequally heated atmosphere, to draw at all heights isobaric surfaces extending from the equator to the poles, on which no voluntary air motion can originate.

In spite of the great rarefaction by the heat of the torrid zone, the atmosphere would nevertheless remain at rest if no disturbance of the neutral equilibrium took place in any part of it. The neutral equilibrium, with the adiabatic temperature gradient belonging to it, is the true condition of the equilibrium and of the relative rest of the atmosphere. This means that (apart from all friction) no expenditure of work is required to bring a mass of air from one height to another; that is to say, that the energy consumed in the expansion of the air under pressure finds its equivalent in the loss of heat by cooling, and *vice versa*. The general prevalence of neutral equilibrium in the atmosphere is therefore the cause of its state of relative rest, and every disturbance of this equilibrium is of the nature of an accumulation of energy and has a tendency to cause currents in the air and thus to restore the condition of neutral equilibrium. The origin of these disturbances is to be sought exclusively in the unequal heating of the air strata

* I must therefore decidedly object to the explanatory statement of Dr. Sprung, "that my assumption of the constant velocity of rotation of the air would be subject to the same error, or at least one very near to it, that vitiated the whole conception of Hadley and Dove as to the influence of the earth's rotation upon the motion of the air." Dr. Sprung quotes, quite improperly as a warrant for this opinion, the memoir by von Hemholtz "Upon atmospheric motions." Von Hemholtz in this mathematical investigation has treated the hypothetical case, viz: "If we consider a rotating ring of air, whose axis coincides with the earth's axis, and which is displaced either northward or southward by the pressure of similar neighboring rings, then, according to the well-known general mechanical principle, the moment of rotation must remain constant." This is undoubtedly correct, since in this assumed case the pressure of neighboring rings does the work of acceleration, but the present question is this: Whether forces are demonstrably present which produce this displacing pressure?

by solar radiation, and in their unequal cooling by the radiation of heat into space. The solar radiation especially heats the earth's surface, and by means of this, the lower air layers contiguous thereto. The excess of temperature thereby produced above the adiabatic ground temperature (which latter corresponds to the average heating of the whole overlying air column), constitutes an accumulation of free energy, like that of a stretched spring, which can be brought into equilibrium again only by such a diffusion of the existing excess of temperature of the lowest strata upward through the entire overlying air column as shall restore the disturbed equilibrium.

Practically this can only be done by means of air currents. In the case of a locally restricted overheating there will originate at any favorable place a bulging upward of the overheated air, which then increases rapidly in height, since the upward thrust increases at a rate proportional to the height of the natural chimney thus formed. But apart from its height, this chimney is to be essentially distinguished from an ordinary one by the fact that it has elastic walls, and that the pressure and density of the air strata inside, as well as outside of it, diminish with height. Thus the air velocity during the up-rush increases in an inverse ratio to the density, since in every minute of time, an equally great mass of air must pass through every section of the chimney. Since, in consideration of the small height of the atmosphere as compared with the earth's radius, no increase of volume with the height need be taken into consideration, therefore, in general, the velocity of the air currents in ascending and descending must increase and decrease with the locally prevailing air pressure.

Hence, also, in the case of an up-rush of air, more of the solar energy accumulated in it is transformed into the *vis viva* of moving masses of air than would be the case without such an acceleration.

In the case of an up-rush of a limited mass of air overheated at the ground, the final result is a local uprush with accelerated velocity up to the higher, and even the highest, air regions, and simultaneously a descent of the air strata surrounding the upward currents, with a velocity diminishing during the descent, and finally a diffusion of the accumulated heat at the earth's surface to all the overlying air strata, with a restoration of the disturbed neutral equilibrium of this part of the atmosphere.

In essentially the same manner, but in its outward manifestation very differently, this restoration of the neutral equilibrium disturbed by solar radiation takes place when the overheating of the air strata adjacent to the ground extends over an entire zone of the earth. In this case the up-rush can no longer be locally restricted, but must systematically surround the whole torrid zone. Neither can it be limited as to time, but the process of adjustment must continue just as long as the causes of disturbance. There must therefore originate a circulatory system embracing the whole atmosphere, which finally performs the

task of conveying the excessive heat of the air strata adjacent to the ground in the torrid zone continuously to the entire atmosphere at all altitudes and latitudes, and thereby restoring, by a progressive circulation, the neutral equilibrium disturbed in the torrid zone.

If—with a consideration of the circumstance that the path of these currents can not intersect, and of the further circumstance that the velocity of the uprising currents must increase with the height in a ratio inversely proportional to the air pressure there prevailing, and finally of the circumstance that the air must retain unchanged the velocity it has once received, until it is destroyed by friction, mixture, or the work of compression,—one attempts to construct the possible paths of these currents, then he will necessarily arrive at the wind system assumed by me, which rests essentially upon the inertia of the overheated air set in accelerated motion by the equatorial updraft. This inertia not only drives the accelerated air in the higher air regions toward the poles, but it is also the cause of its return in the lower strata to the equator.

It would lead me beyond the limited scope of this memoir were I to enter upon a more extended investigation of the inertia effects of this mass of air, or upon the partly modifying influence of aqueous vapor. But permit me to add a few words upon the development of the great local accumulations of energy which find expression in maxima and minima of air pressure. The total air pressure over all parts of the earth must be constant, since this integral represents the unchanging weight of the total mass of air. A local diminution of pressure must therefore be accompanied by an increase of pressure at other places. It is manifestly fruitless to seek the cause of areas of high and low pressure in the local condition of the atmosphere. These areas are frequently announced by the barometer long before any change in the condition of the atmosphere at the earth's surface has occurred. Only light streaks of cloud are frequently wont to betoken a change originating in the higher regions of the atmosphere.

In my memoir, "Upon the conservation of energy in the earth's atmosphere," I have already removed the place of origination of areas of high and low pressure to the higher regions of the atmosphere. In these areas continuous changes of temperature and velocity take place which are derived from the place of up-rush of the air,—that is, from their previous temperature and humidity. If no change of seasons took place, probably a greater regularity would prevail in the upper currents of the air, which then would also give weather relations a definite sequence; such a sequence, up to the present time, has not been detected. We can not judge from what region the air comes which at any point of the earth's surface momentarily flows poleward at higher elevations. The temperature and velocity which this air has depends on the place of up-rush and on the season of the year. Now since the consumption of heat in the up-rising of the air,

and consequently in its compression under pressure, depends entirely on the degree of rarefaction produced, and upon the height of the ascent, then nearly the same diminution of temperature will take place in warm as in cold air.

The excess of heat which the air possessed before the uprush must continue to pertain to the rarefied and cooled air, and hence, at all altitudes, temperature differences must exist of a magnitude similar to those at the surface of the earth.

From this basis, the condition of the atmosphere in general will not be that of unstable, but of stable equilibrium, since the higher air strata, on account of their equatorial tendency, will be on the average warmer and lighter than the adiabatic temperature gradient of the place over which they are found, requires. The higher the excess of temperature of the air before its ascent and the more vapor it contains, the greater must be the velocity which it acquires in rising. In the higher strata of air of middle and high latitudes, relatively warm and therefore light currents of air of great velocity must alternate with the colder and slower flowing ones.

Such a current of air, relatively light and warm, which takes entire or partial possession of the higher levels, destroys the neutral equilibrium of the lower strata. At the surface of contact of the strata, the lower air which is relatively at rest must be under too great a pressure. It must therefore expand and be carried along by the lighter air which flows rapidly above it.

As von Helmholtz has shown, this process must go on with great energy under a wave form. The result must be an expansion and up-flow of the lower air, which will continue until neutral equilibrium, disturbed by the diminished pressure of the upper strata, is again restored.

The inverse case will occur where the air pressure of the upper strata is increased beyond the amount belonging to the elevation, by reason of cooling and of backing up, resulting from the narrowing of the current with increasing latitude. In this case there will be a settling down of the bounding strata, producing a condensation of the lower strata with a corresponding increase of pressure. Finally, in both cases, the disturbed neutral equilibrium must be restored through the action of upward or downward currents, by means of which the air strata lying beneath the sources of disturbance part with or take up air until neutral equilibrium is restored throughout the entire height of the atmosphere.

In order to effect this, the air pressure of the lower strata must increase or diminish until it becomes adjusted to the pressure gradient of neutral equilibrium of the disturbing upper strata. That is to say, the pressure at the earth's surface must change proportionately with the variation of pressure at the elevation itself, whereby the surprising magnitude of the changes of pressure at the earth's surface find their

complete explanation. This change of condition of the lower strata by this mode of adjustment will continue just as long as the causes of disturbance in the upper strata continue. Till then, areas of low pressure with rising currents or areas of high pressure with a downward motion must prevail and set the atmosphere over an extended region into cyclonic motion. Not till the air current in the higher strata of the atmosphere has again reached its normal relations, will a mean barometric pressure and relative rest again prevail at the earth's surface.

The theory of the general circulation of the atmosphere may now be summed up in the following principles:

(1) All motions of the air originate in disturbances of the neutral equilibrium of the atmosphere and serve the purpose of restoring it.

(2) These disturbances are brought about through overheating of the strata of air lying next to the earth's surface by solar radiation, by unsymmetrical cooling of the higher strata by radiation, and by backing up of the moving masses of air in case of the occurrence of resistances to the current.

(3) The disturbances are compensated by rising air currents having an acceleration of such magnitude that the increase of velocity is proportional to the decrease of air pressure.

(4) Corresponding to the upward currents are equally great downward currents in which a diminution of velocity occurs comparable with the acceleration in the case of the rising current.

(5) If the region of the overheating of the lower air is a restricted one, a local up-draft sets in which extends up to the highest part of the atmosphere, and presents the phenomena of whirl pillars, whose interior consists of spirally ascending currents and whose exterior is made up of similar spiral air currents directed downward. The result of these vortex currents is to diffuse the surplus heat of the lower air by which the adiabatic equilibrium was destroyed throughout all the overlying air columns which take part in the vortex motion.

(6) In case the region of disturbance of neutral (or adiabatic) equilibrium is very extended, so as for example to embrace the whole torrid zone, then the equalization of temperature no longer takes place by means of locally uprising vortex currents; now these currents must form and encompass the whole atmosphere.

The conditions of accelerated uprise and of retarded down-flow laid down for the local whirl still hold good, so that the velocity of the air motion at different heights, developed by the energy of heat, is increased approximately in proportion to the air pressure there prevailing.

(7) Since the whole atmosphere (in consequence of the continuous meridional circulation set up and maintained by the energy of heat) must rotate at all latitudes with approximately the same absolute velocity, the meridional currents produced by overheating unite with

the terrestrial current in the great system of atmospheric circulation embracing the whole earth. This circulation serves the purpose of diffusing upwards through the whole atmosphere the excessive heat of the torrid zone, of carrying this equatorial heat and humidity to middle and high latitudes, and of bringing about the development of local air currents at those parallels.

(8) The latter phenomena take place as a result of the production of alternating local increments and decrements of air pressure arising from the disturbance of neutral equilibrium in the higher strata of the atmosphere.

(9) Areas of high and low pressure are consequences of the temperature and velocity of the air currents in the higher strata of the atmosphere.

I consider the investigation of the causes and results of the disturbances of the neutral equilibrium of the atmosphere to be the most fundamental problem of meteorology, and the investigation of the geographical origin of the currents which pass over us on their way towards the pole to be the most important problem in weather prediction.

# THE GULF STREAM.*

By ALEXANDER AGASSIZ.

The Gulf Stream is the best known and at the same time the most remarkable example of the effect of oceanic circulation upon the distribution of temperature in connection with the currents of the North Atlantic. It has long been known to geographers that a cold current coming from Greenland joins the Labrador current, and extends in a southerly direction along the eastern coast of the United States, while a warm current pouring through the Straits of Florida flows in the opposite direction † along the coast of the southern Atlantic States, and is deflected from the banks of Newfoundland crossing the Atlantic diagonally. This body of warm water makes itself felt along the west coast of the British Islands, penetrating even as far as the coast of Spitzbergen, and perhaps beyond, to Nova Zembla. It is impossible to discuss the results of the more recent investigations of the Gulf Stream carried on by the *Blake*, without including the general questions of oceanic circulation, and of the thermal conditions of the Atlantic in particular. I shall therefore briefly state such points, derived from the explorations of the *Challenger* and other expeditions, as will assist us in understanding the history and physics of this great oceanic current.

Sir Charles Lyell has called attention to the fact that in the present epoch the most marked physical feature of the surface of the globe is its subdivision into a land and an oceanic hemisphere. Thomson, like him, looks upon the oceans as continuous, and has happily styled the Atlantic, the Pacific, and the Indian oceans as great gulfs of the Southern Ocean.

The striking hydrographic character of the North Atlantic is its comparative isolation from the Arctic Ocean; the South Atlantic, on the contrary, is fully open to the circulation of cold water coming from the

* From the *Bulletin of the Museum of Comparative Zoölogy*, at Harvard College, in Cambridge, Mass., vol. XIV: chap. ix, pp. 241–259.

† Along the American coast the sudden transition from the green, cold, and more or less turbid water found along the coast and continental shelf, into the deep blue waters of the warm Gulf Stream, is one which has been noticed by all who have passed from the shore seaward. This cold green water, which has such a chilling influence on the climate of the New England States, follows the line of the Atlantic coast of the United States far towards the base of the peninsula of Florida.

Antarctic Ocean. The South Atlantic is shut off from its northern area by the ridge extending from St. Paul's Rocks to Ascension, at a depth of about 2,000 fathoms. The Challenger Ridge runs nearly north and south, leaving a free communication between the Antarctic Ocean and the eastern and western basins of the South Atlantic. The North Atlantic is subdivided into an eastern and western basin at a depth of about 1,500 fathoms by the Dolphin Rise, which follows in a general way the course of the S-shaped Atlantic basin. Ridges separating the Atlantic from the Arctic Ocean extend across Denmark Straits, probably at a shallow depth. From Greenland to Iceland the depth has an average of 500 fathoms; from Iceland to the Færöes, an average of about 300 fathoms, and from there to the Orkneys, of not more than 220 fathoms. From the configuration of the bottom it is evident that a larger amount of cold water must reach the tropics from the Antarctic than from the Arctic regions,* which are shut off from the Atlantic by submarine ridges. Over these and through the channels of Baffin's Bay but a limited amount of cold water can find its way south. In the eastern Atlantic† the principal cooling agent must be the cold water slowly flowing northward from the Antarctic between the Challenger Ridge and Africa.

The shape of the northern extremity of South America, together with the action of the southerly trades, is such as to split the southern equatorial current, and to drive a considerable part of this southern current northward to join the westerly drift which flows to the northward of the Greater Antilles and Bahamas. The phenomena of oceanic circulation in their simplest form are here seen to consist of westerly currents impinging upon continental masses, deflected by them to the northward and eastward, and gradually lost in their polar extension.

There is on the west side of the North Atlantic an immense body of warm water, of which the Gulf Stream forms the western edge, flowing north over a large body of cold water that comes from the poles and flows south. The limits of the line of conflict between these masses are con-

* The temperature line run diagonally across the Atlantic from Madeira to Tristan da Cunha by the *Challenger* brings out the remarkably shallow stratum of warm water of that part of the equatorial regions which corresponds to the regions of the tradewinds both north and south of the equator. The temperatures of the belts of water between 200 and 500 fathoms north and south of the line plainly show that the colder water found south of the equator can not come from the warmer northern belt of the same depth, but must come from the colder belt adjoining the equatorial region. In other words, the cold water may be said to rise towards the surface near the equator; and from the temperature of the two sides of the North Atlantic it is also evident that the supply of cold water flowing from the Antarctic into the Atlantic is greater than that coming from the Arctic regions. This vertical circulation, characteristic of the equatorial belt, is insignificant, however, when compared with the great horizontal oceanic currents.

† In the Pacific the amount of cold water flowing into it through the narrow and shallow Bering Strait is infinitesimal compared with the mass of cold water creeping northward into the Pacific gulf from the depths of the Southern Ocean.

stantly changing, according to the seasons. At one time the colder water from Davis's Straits spreads like a fan near the surface, driving the Gulf Stream to the east,* and at another, large masses of warm water extend towards the Faroe Islands, with branches toward Iceland and the coast of Portugal.

An examination of an isothermal chart of the Atlantic clearly shows the effect of the isolation of the Northern Atlantic, the area of maximum temperature (82°) extends over a far greater space in the North than in the South Alantic. The Gulf of Mexico and the Caribbean become greatly superheated in September (to above 86°), the effect of this superheating in conjunction with the westerly equatorial drift being seen clearly in the northerly extension of the isothermal lines. In the South Atlantic,† owing in part to the greater regularity in the shape of the basin, the difference in the extension of the isothermal lines is but little marked.

The temperature sections of the *Challenger*, from Teneriffe to Sombrero, show remarkably well the great contrast in temperature between the eastern and western basins of the Atlantic, which are separated by the Dolphin Rise. In the eastern basin the cold water on the bottom is supplied by the indraft from the South Atlantic, while the warmer surface water of the western basin is due to the westerly equatorial currents. We seem, therefore, to have masses of water of different temperatures accumulated at certain points by surface or bottom currents, to be distributed again, either north or south, into the general oceanic circulation, thus restoring the equilibrium disturbed by the unequal distribution of heat and cold on the surface of the ocean.

Another temperature section (Fig. 1), which I shall borrow from the *Challenger* soundings, to complement the work of the *Blake* in the same regions, is that which extends from Halifax to the Bermudas, and thence to St. Thomas. The temperatures observed by these vessels show plainly the path of the warm surface water, which flows outside of the West India Islands, and joins the Gulf Stream proper, whose waters when united are banked against the cold Labrador current in its course along the American coast.

Undoubtedly, the early observations made upon the temperature of the ocean were defective, owing to the somewhat imperfect instruments at the disposal of the early explorers; yet they determined the general position of the cold and warm currents of the ocean along our shores.

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* The direction from which the currents come is plainly shown by the nature of the bottom specimens, made up in part of globigerinæ brought by the warmer southerly surface currents, and in part of northern foraminifera and of volcanic sand derived from Jan Mayen and Spitzbergen. The dividing lines between these deposits may be considered as the boundaries of the arctic current where it passes under the Gulf Stream.

† The parallelism of temperature is also very marked in the South Pacific, where there are no disturbing influences. (See J. J. Wild, *Thalassa,* (pl. xv.) and *Challenger* Temperatures.)

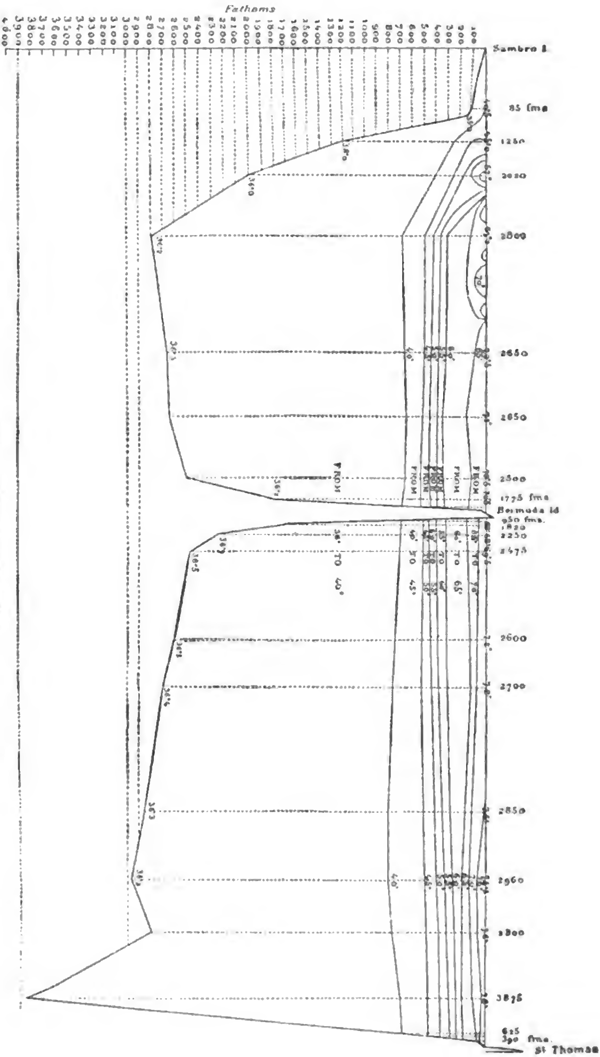



FIG. 1.—*Challenger* observations.

The more systematic work of the officers of the Coast Survey first proved the existence of vast bodies of water, of considerable thickness, and of very different temperatures at corresponding depths, moving in opposite directions. It is to the Coast Survey that we owe the demonstration of the fact that the waters of the polar regions pour into the tropics along the bottom, just as the warmer equatorial waters flow across the temperate zones near the surface, and make their influence felt in the polar regions.

The submarine ridges interrupt the flow of these cold polar waters, and form the so-called closed basins, with a higher bottom temperature than that of the adjoining oceanic basin. The effect of such ridges upon the bottom temperature was first traced by the soundings of the *Porcupine* in the North Atlantic and in the Mediterranean. Subsequently the *Challenger* discovered several such inclosed seas while sounding in the East Indian Archipelago.

The correctness of these results has been confirmed by the Coast Survey, from soundings in the Caribbean and in the Gulf of Mexico; their bottom temperature (at a depth of over 2,000 fathoms) is exactly that (39½°) of the deepest part of the ridge, at about 800 fathoms, which separates them from the oceanic Atlantic basin, with its temperature of 36° at the depth of 2,000 fathoms.

The presence of thick layers of water having a higher bottom temperature than that of adjoining areas would indicate the presence of ridges isolating these warmer areas from the general deep-sea oceanic circulation. A map of the Atlantic, made entirely with reference to the temperatures, would correspond to a remarkable degree with the topography of the bed of the ocean, and show how and where the breaks in the continuity of the circulation, both for the arctic and antarctic regions, occur in the Atlantic.

It was not however until the Miller-Casella thermometer came into general use for deep-sea investigations that a degree of accuracy before unattainable in oceanic temperature became possible. It soon was a well-recognized fact that as we go deeper the temperature diminishes, and that at great depths the temperature of the ocean is nearly that of freezing. In 1868–'69, in the Faroes Channel, the *Porcupine* found a temperature of —1.4° C. at a depth of 640 fathoms, and a temperature of 0° C. at 300 fathoms, this being a southern extension, as was subsequently found, of the deep basin of 1,800 fathoms lying between Norway and Iceland. The same temperature, 0.9° C., occurs under the equator at a depth of about 2,300 fathoms, while 5° C. is found at a depth of 300 fathoms. As early as 1859 the Coast Survey had recorded in the Straits of Florida a temperature of 40° F. (4.4° C.) at a depth of 300 fathoms, while at the surface the temperature was 80° F. (26.7° C.). Beyond 1,000 fathoms the temperature diminishes very slowly. The *Challenger* also found a temperature somewhat below zero off the Rio de la Plata, at a depth of about 2,900 fathoms.

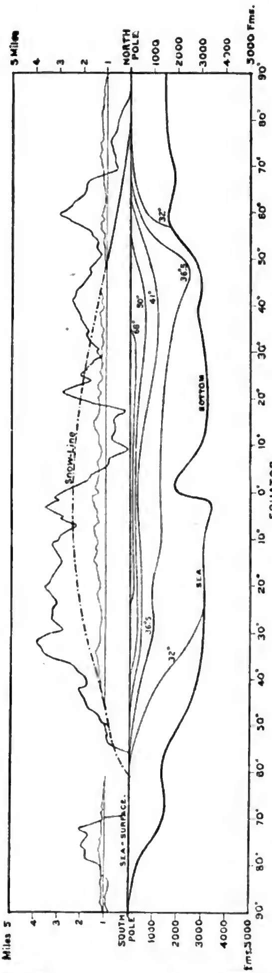



Fig. 2.

The temperature of the oceanic basin depends upon the depth, the latitude, the currents, and the seasons; that of mediterraneans (land-locked seas) is controlled by other causes, which will be more fully discussed when we come to treat of the temperature of the Caribbean and of the Gulf of Mexico. The constants are the depths and latitude, while the disturbing elements are represented by the varying atmospheric and oceanic currents and the seasons.* The effects of seasonal differences of temperature do not extend to great depths, yet act with sufficient power greatly to modify the force and volume of the oceanic currents. As a general rule, the temperature diminishes from the surface toward the bottom, a belt limited in depth (about 150 fathoms) alone, being subject to variations due to the action of the sun. Below that the temperature generally decreases with the depth, until we reach the body of water of which the temperature may in general be said to be uniform (about 35°).†

As explanations of the oceanic currents, we have first the gravitation theory, which looks upon the differences of temperature and of specific gravity of the water at the equator and poles as the prime cause of oceanic circulation; next, Thomson's theory, according to which the difference in evaporation and precipitation between the northern and southern hemispheres causes a consequent heaping up of water in the south-

* Dr. J. J. Wild has given in "Thalassa" an excellent diagram, showing at a glance the general relations of the temperature in the liquid envelopes to the earth's crust. It is here re-produced (Fig. 2), slightly modified.

† As currents sink as soon as their temperature falls below that of adjoining waters, and as the temperature diminishes from the surface toward the bottom, as well as from the equator to the pole, a combination of these varying elements may produce a somewhat complicated circulation.

ern hemisphere, which south of latitude 50° is completely covered by water; thirdly, the theory which attempts to account for the circulation by the *vis inertiæ* of the equatorial waters; and, lastly, the theory which considers the trade-winds and other prevailing winds as the principal causes by which oceanic currents are produced. Franklin, Humboldt, Rennell, Sir John Herschel, and Croll have supported this view of the origin of oceanic currents.

Of course, until the extension of the frictional effect of winds to great depths has actually been measured, the last theory, plausible as it may appear, lacks its final demonstration. It is by no means proved, because there is an apparent connection in time between the periodic variations of the currents and of the trade-winds, that we must seek in the latter the only cause for the existence of the former. The presence of the Guinea Stream, the position of the regions of calms in the northern and southern hemispheres, the diminishing force of the trade-winds as we approach the equator, the rise of the colder strata of water to shallower depths in the equatorial than in the temperate regions, are phenomena which the action of the trade-winds alone does not seem to explain. Why may not oceanic circulation, like the movements of our atmosphere, be dependent upon cosmic phenomena, practically independent of any secondary causes, and modified by them within very narrow limits?

The difference in salinity of certain oceanic districts is in itself insufficient to explain oceanic circulation; so that while the secondary causes referred to above are undoubtedly active as producing more or less extensive local circulation, we seem justified in looking upon the differences of temperature of the zones of the ocean as the principal cause of the general oceanic circulation. We may state, in the main, that the density of the ocean water is least at the equator, gradually rises toward the poles, and attains its maximum at 60° of latitude. For the sake of convenience we may call the density of the ocean as one at a depth of 500 fathoms, and consider the strata of water above and below as having a less and a greater density,* within very narrow limits; thus the watery envelope is not in a state of equilibrium.

The most important disturbing factors of a uniform distribution of oceanic temperature are the continental masses which lie in the path of the equatorial currents. A comparison of the position of the oceanic isotherms of the North and South Atlantic shows a striking contrast in their course north and south of the equator. A similar comparison between the Atlantic and Pacific brings out plainly the contrast in the course of the isotherms of two oceans, in which the disturbing effect is due in the one to continental masses and in the other to large groups of oceanic islands.

*Ocean water, at depths exceeding 1,000 fathoms, has a temperature of nearly 35° F., the temperature of greatest density. Should the water become either colder or warmer, it must expand; this it can not do, on account of the pressure.

Perhaps the best example of the unstable equilibrium existing between adjoining oceanic areas is furnished by the heaping up of the waters driven by the tradewinds into the Gulf of Mexico from the Caribbean. The amount of this accumulation has actually been measured by officers of the United States Coast Survey. It gives an additional force at work to keep up the efficiency of the Gulf Stream. The Gulf of Mexico is considered by Mr. Hilgard as an immense hydrostatic reservoir, rising to the height of more than 3 feet* above the general oceanic level, and from this supply comes the Gulf Stream, which passes out through the Straits of Bemini, the only opening left for its exit.

Arago, Lenz, and Leonardo da Vinci before them, maintained that, since the water of the equator was greatly heated and lighter and attained a higher level, there was a flow of the surface waters towards the poles, a compensation being established by the flow of lower strata from the poles to the equator. The principal features of this thermic theory have of late found their most efficient exponent in Dr. Carpenter. The results of his experiments to prove this theory upon a small scale seemed to show that the cooling of the waters at the pole and their rapid fall were a more efficient force than the heating of the water at the equator. Ferrell has called attention to the phenomenon that cold water at the bottom will be swung more to the westward than the water at the top, which will be turned in an easterly direction. As the particles of water ascend, they retain the velocity they had in deeper parts of the ocean, and thus, when reaching either the surface or lesser depths than their original position, they must show themselves as producing a westerly current. This current, deflected by the continental masses as it strikes the east coast, would then be set in motion towards either the north or south pole. At the equator, the water which flows westward from the eastern shores of the continental masses can only be replaced by the compensating waters flowing to it from the north and south. This circulation fairly agrees with the phenomena observed in the South and North Atlantic.

It is interesting to trace the gradual development of our knowledge of the Gulf Stream and to see how far-reaching has been the influence of the oceanic currents upon the explorations of maritime nations, and the effect these have had in their turn on the discovery of America and its settlement.† The hardy Norse navigators, nearly five hundred years before Columbus, sailed along the eastern shores of Greenland and America, and extended their voyage possibly as far south as Narragansett Bay, following the Labrador current, which swept them along our eastern shores. It was well known to navigators that upon the

* By a most careful series of levels, run from Sandy Hook and the mouth of the Mississippi River to St. Louis, it was discovered that the Atlantic Ocean at the first point is 40 inches lower than the Gulf of Mexico at the mouth of the Mississippi.

† See Kohl, J. G., *Geschichte des Golfstroms und seiner Erforschung*. 1868.

western shores of Norway and the northern coast of Great Britain driftwood of unknown timber and seeds of plants foreign to the temperate zone were occasionally stranded, coming from shores where probably no European had as yet set foot.

The Portuguese navigators, sailing west, came beyond the Canaries to an ocean covered with seaweed (the gulf-weed of the Sargasso Sea), through which none dared to push their way, and the problem of the "Sea of Darkness" remained unsolved until the time of Columbus. He possibly was familiar with the traditions of the voyages of the Norsemen and undoubtedly had access to more or less accurate information regarding the Atlantic, accumulated previous to his time in the archives of Portugal and Spain or circulated among the sea folk of that day, and this information included legends of lands to the west. Columbus started under the full persuasion that he could reach the lands from which the remarkable products brought by the currents had originated. When he came into the region of the northeast trades and found himself swiftly carried westward, not only by the winds, but also by a current moving in the direction of the trades, his return seemed very hazardous, unless he could strike upon that opposite current which had borne the trees and seeds to the northern coasts of Europe. Obliged by the trades to take a northerly course on his way home from Hispaniola in 1493, he came upon the region of variable and westerly winds, with a current setting in the same direction. Columbus was thus the first to introduce the circular sailing course which, up to the present day, vessels sailing from the West Indies to Europe are compelled to take. They come before the wind with the trades, make the Windward Islands, and, sailing northward, find their way through the Windward or the Mona Passage, until they reach the belt of variable and westerly winds, when they steer toward the European shores again.

After reaching the Mexican coast, Columbus, by one of his broad generalizations, practically discovered the Straits of Florida, arguing that it must have an outlet into the Atlantic and that he would thus escape the tedious voyage in the teeth of the northeast trades, which would be his lot if he attempted to find his way home by the usual route of the Windward or the Mona Passage. In 1519, an expedition inspired by Alaminos was dispatched by Garay, governor of Jamaica, to follow the easterly current running along the northern shores of Cuba. The expedition, however, did not succeed in passing to the eastward of Cape Florida.

An accurate knowledge of the currents and winds enabled the freebooters of the sixteenth century to carry on their depredations with impunity, and their successors, the wreckers of the Florida reefs and Bahamas, made use of their intimate knowledge of the coasts and of the winds and currents to obtain commercial advantages, not always by the most honest methods. With the mapping of the reefs by the

Coast Survey all this has disappeared, and the lighting of the great highway of the Straits of Florida has reduced to a minimum the dangers of navigation, though the Tortugas are still a favorite resort, even in broad daylight, for old ships properly insured.

The captain of one of the Spanish vessels was carried south, off the coast of South America, by the current which sweeps from Cape St. Roque along the shores of Brazil, and involuntarily discovered the Brazilian shore current. Though these different currents were known to exist in the Atlantic, the most crude notions of their origin and course prevailed. (Fig. 3.) According to Columbus, at the equator the waters of the ocean moved westward with the heavens above, rolling over the fixed earth as a center. It was only in the seventeenth century that physicists began to suspect a connection between the currents and the rotation of the earth, a view afterwards maintained by Arago and Humboldt.

The first scientific basis for the exploration of the Gulf Stream was undoubtedly due to Franklin. At the time he was Postmaster-General of the colonies, his attention was called to the fact that the royal mail packets made much longer passages to and from Europe than the trading vessels of Massachusetts and Rhode Island. On talking the matter over with Capt. Folger, of Nantucket, he first learned the existence of a strong easterly current, of which the New England captains took advantage in going to Europe, and which they avoided by sailing a northerly course on the home voyage. Folger also called Franklin's attention to the fact that this current was a warm one.* He and Dr. Blagden becoming interested in the question, Franklin set out to ascertain the size of the current and its temperature. Soon after, Franklin published the first chart of the Gulf Stream (Fig. 4), for the benefit of navigators, from information obtained from Nantucket whalemen, who were extremely familiar with the Gulf Stream, its course, strength, and extent.

From the time of Franklin until the problem of the Gulf Stream was again attacked, in 1845, by Franklin's descendant, Prof. A. D. Bache, of the United States Coast Survey, many ingenious theories were published, but nothing was added to our knowledge of the origin and structure of the Gulf Stream. Humboldt, Arago, and others attempted to trace in the Gulf Stream a secondary effect of the trade-winds, and of the rotation of the earth. The officers of arctic expeditions sent to Spitzbergen did not fail to see the effect of a mass of warm water passing northward, and Von Baer was among the first to consider this body of water as an eastern extension of the Gulf Stream. Meanwhile the arctic explorers of Baffins Bay and western Greenland found themselves baffled in their efforts to reach high latitudes by the powerful

* It was noticed by Lescarbot, in 1605, that far north there was a mass of warm water moving toward the east, and that both north and south of it the water of the Atlantic was cooler.

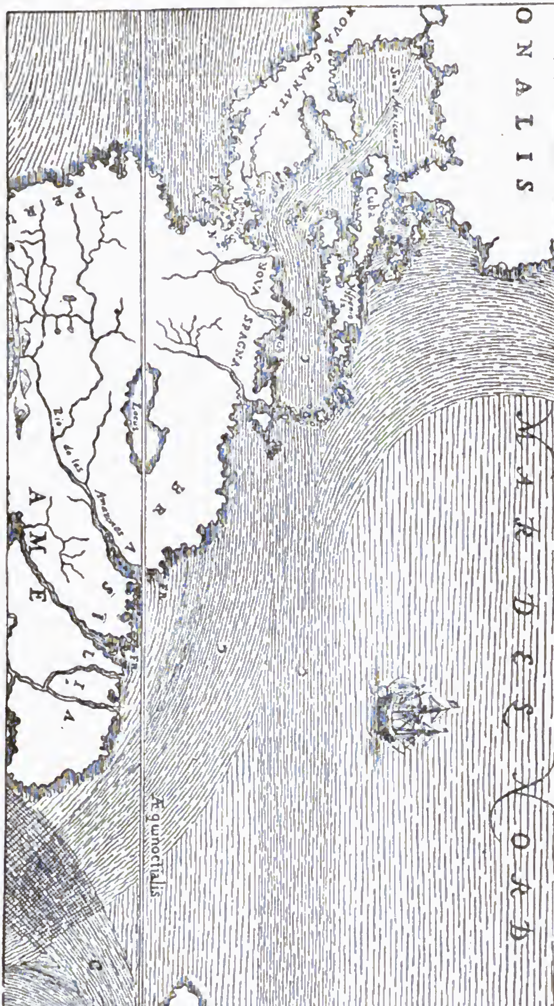



Fig. 3.—OCEANIC CIRCULATION. MAP OF THE 17TH CENTURY.
(From Athanasii Kircheri. E. Soc. Jesu Mundus Subterraneus Editio tertia Amstelodami, 1678.)

southerly current, carrying with it fields of ice or huge icebergs, which had found their way south below the southern limits of the Banks of

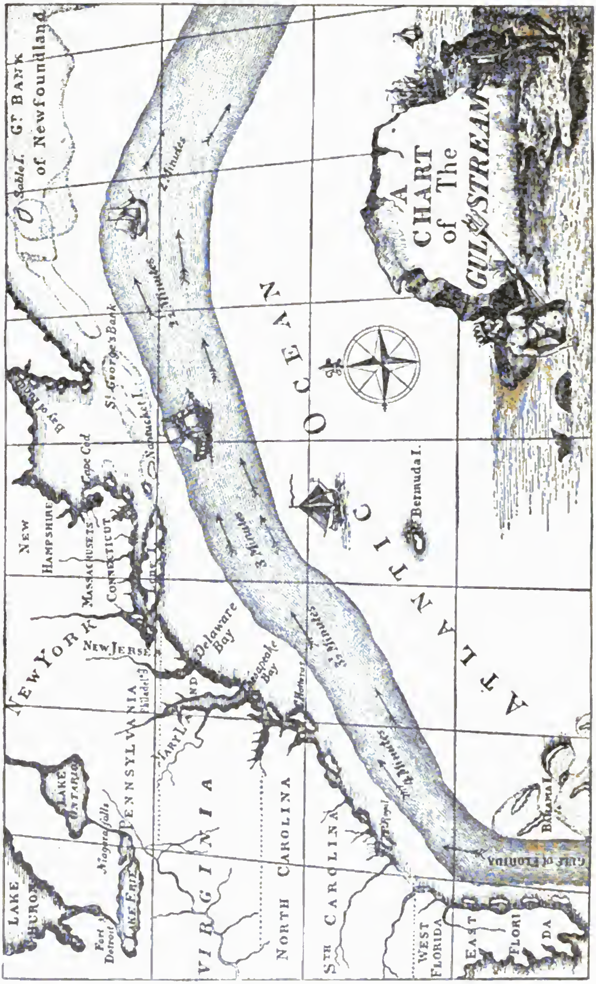
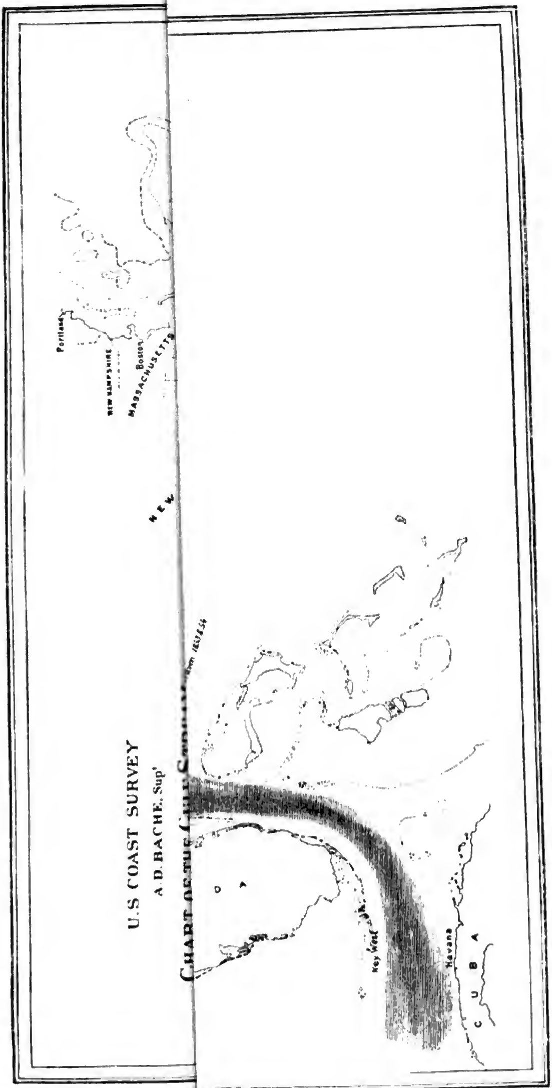


Fig. 4.—Franklin's Chart of the Gulf Stream.

Newfoundland, and even beyond the latitude of Cape Cod and Nantucket Shoals.


U.S COAST SURVEY
A.D.BACHE, Sup't
Portland
NEW HAMPSHIRE
Boston
MASSACHUSETTS
Key West
Havana
CUBA

The earlier work of the Coast Survey in its investigations into the structure of the Gulf Stream (1845 to 1860) consisted in making sections across the stream, from the Straits of Bemini as far north as the latitude of Nantucket. From the studies of Craven, Maffitt, Bache, and Davis were developed the so-called cold and warm bands, believed at that time to be the principal characteristic of the Gulf Stream. The accompanying map (Fig. 5), published in 1860 by the Coast Survey, will serve to illustrate the structure of the Gulf Stream as it was then understood; namely, as a succession of belts composed of warm northerly currents flowing side by side with a cold southerly current, or of a cold southerly current which had found its way under the warmer northerly currents. These alternating belts had no definite position, the size of the colder bands and warmer belts being dependent, the one upon the force of the arctic current, the other upon that of the tropical

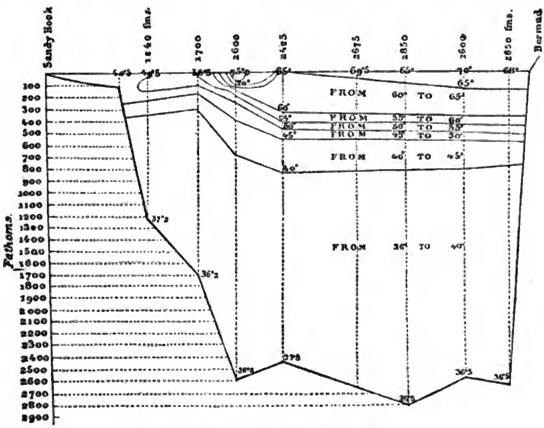



FIG. 6. —*Challenger* observations.

current, increased in breadth and volume beyond the Bahamas by the whole of the warm belt of surface equatorial water, which is deflected northward by the Windward Islands, instead of forcing its way through the passage between the Windward Islands, the Mona and Windward passages, and the Old Bahama Passage.*

*Great as is undoubtedly the effect of the Gulf Stream proper (Fig. 6) in increasing the temperature of the water in northern latitudes subject to its influence, we must not forget to add to it that of the greater mass of heated water which is forced north, and finds its way to the northernmost shores of Siberia, losing in its passage the heat it has accumulated within the tropics. So that, while we can not say that the Gulf Stream has disappeared, and has been replaced off the Banks of Newfoundland by the equatorial drift, neither can we attribute to the Atlantic drift alone the masses of warm water found in the basin of the northern part of the North Atlantic. (See Figs. 1 and 6.)

Commander Bartlett found no warm or cold bands, no distinct cold wall, and no bifurcations in the surface waters till he came off Hatteras. Near the shore the current was greatly influenced by winds. The work of the *Blake* seems to show that the cold bands, so called, which figure so largely in all early descriptions of the Gulf Stream, have no regularity, and only represent at any given moment the unceasing conflict going on between layers of water of different velocities and of different temperatures. Such a conflict is perhaps the well-known rip we encountered off Charleston, which may be caused by a struggle between portions of the Labrador current passing under the Gulf Stream. As the isotherms rise and fall with the irregularities of the bottom, where water accumulates or piles against ridges, hot and cold bands may be flowing one above the other. We need however more prolonged observations to show how far below the surface these bands extend. Commander Bartlett, from the last Coast Survey investigations under his direction, is inclined to consider the cold bands of the Gulf Stream as quite superficial.*

A cold current striking against a warmer stream that is flowing in the opposite direction may split it into more or less marked hot and cold bands. Bands similar to those of the Gulf Stream were observed by the *Challenger* in the Agulhas current off the Cape of Good Hope, and off Japan in the Kuro Siwo.

It is of course difficult to ascertain the part taken by the trade-winds in originating the oceanic circulation of the Atlantic. That winds blowing steadily from one quarter give rise to powerful currents is well known, and it is not difficult to imagine the prominent part the trades must play in setting in motion, in a southwesterly and a northwesterly direction, the mass of water over which they sweep so persistently on each side of the equator.

The change of currents in the Indian Ocean due to the shifting of the monsoons is well known. How far below the surface this action of the winds reaches, is another question.† Theoretically it has been calculated by Zoeppritz that one hundred thousand years is ample time to allow the friction of the particles to extend from the surface to the bot-

* In sailing from Halifax to the Bermudas, Sir Wyville Thomson speaks of passing alternate belts of cold and warm water. Early in the morning of the 22d of May, the surface water was of a temperature of 17° C.; at midnight it had fallen to 12° C., to rise again half an hour later to over 15° C. Thus, from the time the *Challenger* left Halifax with a surface temperature of 4° C., gradually rising to 10° C. until she encountered the Gulf Stream proper, marked by a rapid rise of temperature, she passed through alternate belts of warm and cooler surface waters varying between 18° C. and 23° C.

† The movement arising from the action of the winds on the surface is transmitted by friction from one layer to another and communicates the velocity of the upper particles to the underlying layers in succession. If this is continued long enough, the velocity of the lowest layers will equal within a fraction that of the upper layer.

tom, say to 2,000 fathoms, were the winds to blow without intermission in one direction during that time, with the average power they are known to possess.*

We may imagine the whole of the mass of the Atlantic within the belt of the trade winds to be moving in a westerly direction and impinging upon the continental slope of South America,† and upon the Windward Islands, at which point it is deflected either in a southerly or northerly direction or forces its way into the Caribbean. In our present state of knowledge it is difficult to trace the path of the equatorial water as it is forced into the eastern Caribbean. Commander Bartlett supposes that it is warmed in the Caribbean by circulating round the whole basin. The water which is swept into the Caribbean by the trade winds through the passages between the Windward Islands and, being then driven into the Old Bahama Channel funnel, flows through the Windward Passage, represents a far greater mass than that which can find its way into the Gulf of Mexico through the Straits of Yucatan or that of the stream flowing north through the Straits of Bemini. This is the actual Gulf Stream, a body of super-heated water filling the whole straits; it has an average depth of about 350 fathoms and a velocity extending to the bottom of at least 3½ miles an hour.‡

The section of the Yucatan Channel is too small to allow for an outflow equal to the inflow into the Caribbean,§ so that, after the trades have ceased to force the equatorial water into the Caribbean basins, it must remain there a considerable length of time before it passes into the Gulf of Mexico, where, owing to similar differences between the rate of inflow and outflow, the water must still become more super-heated.

We must therefore consider the Gulf Stream proper, as it emerges from the Straits of Bemini, as an immense body of super-heated water

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* It is therefore possible that currents which owe their existence to causes that have been modified to a certain extent should still exist in the ocean long after the conditions producing them (acting from the surface) have ceased to be effective by any break of continuity due to the interposition of islands or of banks in the track of oceanic currents.

† Did the Gulf Stream not meet continental masses, it would simply expand north and south, losing its initial velocity, and gradually cool down towards the poles, the cold penetrating all the deeper portions of the ocean, just as we find it reaching the higher summits that rise above the line of perpetual snow.

‡ Current observations taken by Mitchell off the coast of Cuba, in the deep part of the Gulf Stream, show that it has a nearly uniform and constant velocity for a depth of 600 fathoms, although the temperature varies 40° F.

§ A part of this water emerges again at a higher temperature between Guadeloupe and Haiti and joins that portion of the equatorial current which finds its way into the Windward Passage. This increased temperature may be due to its passing over shoals and banks at the northeastern end of the eastern basin of the Caribbean.

retaining an initial velocity which originated in lower latitudes, then losing both its velocity and its heat on its way north.*

The Straits of Florida have a width of about 48 miles between Jupiter Inlet and Memory Rock; the greatest depth is 439 fathoms, and the cross-section 430,000,000 square feet. At three knots, the delivery would be, as calculated by Commander Bartlett about 436,000,000,000,000 tons a day, an amount of warm water far less than we find over the North Atlantic, which, as has been shown, is derived from the western set of the equatorial current, joining the Gulf Stream in its way towards European shores.† (See Figs. 1–6.)

Commander Bartlett thus describes the general course of the Gulf Stream:

"The Gulf Stream has for its western bank the 100-fathom curve as far as Cape Hatteras. It has a depth of 400 fathoms as far as Charleston, where it is reduced to 300 fathoms; but the Arctic current has for its western bank the 1,000-fathom curve, which is quite close to shoal water from the George's Bank to Hatteras.

"The average surface temperature in the axis of the stream rarely exceeded 83° F. in June and July. On one or two occasions the thermometer read as high as 86° and once 89°; but it was at high noon in a dead calm. The temperature at 5 fathoms did not range above the average of 81½°.

"The increase of temperature of the surface was found as we entered the current. . . .

"The surface temperatures did not indicate a cold wall inside of the stream and the water inside of the 100-fathom line to the shore seemed to be an overflow of the stream, as the temperatures to 5, 10, and 15 fathoms were nearly as high as those found in the stream.

"The temperatures at the bottom in the stream, at corresponding depths, were the same as those found in the Windward Passage, and

* Between Halifax and the Bermudas, the section of the Gulf Stream observed by the *Challenger* was cooled 1° C., as compared with that of the Bermudas to New York. The Gulf Stream retains its heat as a surface current as long as the temperature is sufficiently high to make it lighter than the surrounding water. Its greater salinity causes it to sink below the comparatively fresher water of northern latitudes. Similarly, the Arctic current, when it reaches a certain latitude along our eastern coast, sinks from its greater specific gravity below the warmer surface currents and continues its way south as an undercurrent of cold water.

† It might, perhaps, be advisable to distinguish between the eastern extension of the Gulf Stream, combined with the Atlantic drift, and the Gulf Stream proper, understanding by the latter the water which passes through the Florida Straits. This has been called by Petermann the Florida Stream; and the name of Gulf Stream has been applied to the vast body of warm water which super-heats the basin of the Eastern Atlantic to the eastward of 45° west longitude. There seems to be no reason for changing the name of the Gulf Stream because so many other liberties have been taken with it. We should retain the original name, limiting it to the Florida Stream coming from the Gulf of Mexico and applying to its eastern extension, in connection with the Atlantic easterly drift, some new name, such as Equatorial Drift or the Caribbean Stream.

in the course of the current to the Yucatan Passage. The average bottom temperature at 400 fathoms was 45°, and, as off Charleston,* in 300 fathoms, 53°. The temperature at 300 fathoms, off the George's Bank, was found in July to be 40°; and this last was the temperature that we found at the same depth just north of Hatteras and the Gulf Stream.

"I have stated that the surface temperatures did not show a cold wall inside the stream; but the bottom temperatures give a narrow cold section close to the 100-fathom curve all along the course of the stream from Hatteras to Florida. Soon after leaving the Straits of Florida there is a division of the stream shown by the bottom temperatures, part following the coast and the remainder branching off to the eastward. - - -

"We found that 3 knots was a general average to allow for the whole stream. This would give a greater velocity at some central point. Between the Bahamas and Florida the average was exactly 3 miles per hour; but for a distance of 15 miles in the axis of the stream it was as high as 5.4 miles per hour. To the northward of the Bahama banks, and to the eastward of the stream, there was a slight current setting southeast. We found the direction of the current in the stream very much affected by the wind, sometimes inclining it to the east, then to the west.†

"In the latter part of June, 1881, we were hove to, some 50 miles east of the Gulf Stream, off Charleston, where we experienced a current of 3 miles per hour, setting southeast; wind blowing a gale from southwest.‡

"The sudden rise of the plateau off Charleston, together, probably, with the meeting of the arctic and warm currents, creates a remarkable disturbance at this point. - - -

*About 80 miles from Charleston a line was run parallel to the coast, along the axis of the Gulf Stream.

| Depth in Fathoms. | Surface temperature. | Temperature at 2 fathoms. | Bottom temperature. | Nature of bottom. |
|---|---|---|---|---|
| | *Degrees.* | *Degrees.* | *Degrees.* | |
| 257 | 83 | 83 | 50 | No specimen. |
| 291 | 83 | 83.5 | 45 | Fine sand. |
| 274 | 83.5 | 83.5 | 44.5 | Coarse sand. |
| 288 | 87.5 | 83.5 | 45 | No specimen. |
| 265 | 84 | 83.5 | 45 | Coarse sand. |

† Inshore of the Gulf Stream, though a southerly current was distinctly traced inside the 100-fathom line, yet the temperature of the water towards the shore was but little cooler than that of the stream itself; the same is found to be the case if we examine the temperature sections of the eastern edge of the Gulf Stream. The stream itself seems to be mainly characterized by its velocity and by its color.

‡ On the southern side of the Gulf Stream Commander Bartlett observed immense quantities of gulf-weed; this is also blown into Narragansett Bay in considerable quantities, covered with clusters of floating barnacles.

"We crossed the stream six times in this locality, under conditions of weather from a calm to a strong breeze, and always crossed, near the center of the stream, bands of rippling water several miles in width. It is very like the rip at the entrance to Long Island Sound."

The Gulf stream flows at the rate of about one-fourth of a mile an hour through the Yucatan Channel, which is 90 miles wide and over 1,000 fathoms deep. Through the Straits of Bemini it has a velocity of from 4 to 5 knots, a width of 50 miles, and an average depth of 350 fathoms. This velocity rapidly decreases as we go north. Off St. Augustine it is rarely more than 4 miles; from there to New York it decreases to 2½ miles per hour; off the banks of Newfoundland it is reduced to 1½ or 1 miles; and at a distance of 300 miles to the eastward the velocity of the Gulf Stream, which has constantly been spreading out fan-shaped, is scarcely perceptible.

As far as the current observations of the *Blake* may be trusted, they indicate a greater speed in the axis of the Gulf Stream than along its edges—a velocity varying between 2 miles an hour, or even less, and fully 5 miles. The width of the stream off the east coast south of Hatteras varies from 50 to nearly 100 miles.

The observations of the *Blake* show that the bottom of the Gulf stream along the Blake Plateau is swept clean of slime and ooze, and is nearly barren of animal life.

## ON THE ABSOLUTE MEASUREMENT OF HARDNESS.*

By F. AUERBACH.

Translated by CARL BARUS.

Hardness, aside from its practical importance, is one of the most remarkable properties of solid matter. This is shown at once by the difficulties which have been encountered in the endeavor to arrive at an accurate interpretation of it. Indeed, the attempts to solve questions relating to hardness are of very great variety, and are exceptionally large in number, and they have in a measure led to some interesting results; but the subject in its broader bearings has not yet been attacked with success, nor has a rigorous definition of hardness been established. Problems which present themselves in dealing with any of the physical properties of a body may usually be divided into three sub-problems: The first among these includes the scientifically exact description of the conception in question, so that the property may henceforth be treated as a purely mathematical variable. Then this quantity is to be measured, and methods and apparatus must be devised for that purpose. Finally, the measurements are themselves to be generalized by being extended to as many bodies under as many different circumstances as possible. At the outset, however, it is by no means necessary that the procedure adopted should be so simple as to be of immediate practical utility. As a rule this will only be attained at a much later stage of the research. The chief aim at the beginning is to work forward from some theoretically perfect basis, and to so fashion the methods that the end in view may be reached with a reasonable degree of accuracy as well as certainty. To within a few years none of the three sub-problems which I have mentioned can be said to have been solved. To Hertz belongs the credit of being the first to push the question to an issue. His ingenious reasoning is particularly fortunate, inasmuch as it harmonizes the general conception of hardness and the earlier definitions which were given of it in all essential and necessary points and to the exclusion of errors of principle and vagueness. Taking Hertz's conclusions as a point of departure, I believe I have solved the second of the sub-problems, and in the present paper submit a method, which (with

*From the *Annalen der Physik und Chemie*, April, 1891; (new series) vol. XLIII, pp. 61-100.

the exception of a single point as yet in need of further elucidation), seems to lead to satisfactory results, both from a theoretical and a practical point of view. My paper is therefore divided into the following parts:

§ 1. A review of the earlier work.
§ 2. The theory, in so far as it enters into my work.
§ 3. The method in general.
§ 4. The description of the apparatus.
§ 5. General remarks on the observations.
§ 6. The constants and the sources of error.
§ 7. The experimental verification of the method.
§ 8. The measurement of the elasticity and the hardness of certain substances.

With reference to the last I will state at once that the data are given solely with the object of evidencing the utility and accuracy of the method. They show to what degree the second sub-problem has been solved. Systematic work relative to the third sub-problem, as well as many investigations which the present paper suggests or implies, I have reserved for future communications.

## I. A REVIEW OF THE EARLIER WORK.

Relative to the definition and the measurement of any physical quantity like hardness, the observer may proceed from three points in view. He may only wish to find out whether the hardness of any given body is greater or less than the hardness of another given body; and he may therefore be satisfied with a typical series, any member of which is conventionally harder than the preceding and softer than the succeeding body. The elements of such a series may even be numbered; but the numbers are obviously not significant quantities. Furthermore, if even these members are reliable it is clearly to be shown (1) whether if $B$ be harder than $A$, $A$ is always necessarily less hard than $B$; (2) if when $C$ is harder than $B$ and $B$ harder than $A$, $C$ is always harder than $A$. In the case of many physical properties these conditions do not hold, or do not hold at least for all substances; and it is, therefore, not generally possible to classify bodies in a scale of the kind in question. Only after these fundamental conditions have been fixed in principle, is it permissible to make the second step, namely, to replace the more or less arbitrary members in the scale of hardness, by data which actually measure the property, and which therefore, for any two bodies, will express the hardness ratio. The scale so obtained is relative, and the term of comparison conventionally chosen. Thus, for instance, the hardness in a given definite body may be taken as the unit. But here again it is necessary to reflect that the data may differ not only as to their actual value, but in their relations, depending as they must on the experimental method by which they were obtained. Only the final or absolute method is, therefore, always satisfactory, for here the

hardness of each substance is expressed, irrespective of other substances and without reference to a normal body, in terms of the fundamental units of physics.

The method of rating hardness by scratching is best known and most generally applied. One body is harder than another, if a point or sharp edge of the former is capable of scratching a plane over face of the latter. Of the two conditions which make an arbitrary scale possible in this case, the first is approximately given, to the extent only that the differences of hardness to be rated are in any two bodies marked. If this differences is small, it is usually found that a sharp edge of either will scratch a plane surface of the other. It is customary to refer this discrepancy to the sensitiveness of the method. The two bodies are flatly pronounced equally hard, and since the second of the conditions above given is also borne out by all the cases hitherto tested, a rough scale of hardness is thus feasible. The first investigator who made use of such a scale, Hauy, confined his work to four steps. They were limited by calcite, glass, and quartz. Mohs increased the number of steps to ten, and although later mineralogists, believing some of the steps disproportionately large, have inserted intermediate degrees, the Mohs scale has in general been retained to the present day. Indeed the justice of this is apparent, for in view of the absence of any means of even approximately defining the relative values of the successive degrees, all attempts to reduce them in size would, in the long run, rather be productive of error than of increased accuracy.

The first attempt at measurement was made by Frankenheim,* who estimated the hand pressure under which a given hard point or stylus leaves a scratch on the surface to be tested. But instruments by which this pressure or the depth of penetration of the stylus is actually registered were not invented till much later. They are due, respectively, to Seebeck,† Franz,‡ Grailich and Pekàrek,§ F. Exner,‖ Pfaff,¶ Turner,** and others, and have been called "sklerometers." The results obtained by these forms of apparatus, as Exner himself admits, are not of the nature of measurements, for all true measurements of an unknown quantity determine the latter by inclosing it between well-defined limits, and it is by the distance apart of these limits that the accuracy of the method is conditioned. Sklerometers however are capable of furnishing only an upper limit. The lower limit is left to conjecture.

*Frankenheim: *De cohæsione*, etc., Inaug. Diss., Breslau, 1829.

†Seebeck: *Progr. Cöln.* Real-Gymn., 1883.

‡Franz: *De lapidarum duritate* Inaug. Diss., Bonn, 1850; Pogg. Ann., vol. LXXX, 1850, p. 37.

§Grailich u. Pakàrek: *Wien. Ber.*, vol. XIII, 1854, p. 410.

‖F. Exner: *Unters über d. Härte an Krystallflächen*, Wien, 1873.

¶Pfaff: *Münch Ber.*, 1883, pp. 55, 372. Pfaff's invariable use of the term "absolute hardness" is quite unjustifiable. His data are relative at best."

**Turner: *Proc. Birm. Phil Soc.*, 1887, vol. V (2).

Seebeck's only advance on Frankenheim is a transfer of judgment from the hand to the eye, the latter being confessedly more skillful in making estimates. At best, however, the method thus established encounters the following serious disadvantages. In the first place, the results obtained depend on a variety of minor conditions, foremost among which is the nature of the material out of which the stylus is made. Steel is most generally used, but steel can not be exactly defined, and therefore the observer has no right to assume that his stylus is a body of fixed properties. Moreover, the necessity of using both hard and soft steel in the apparatus introduces a further complication, but, as a matter of fact, when a hard steel stylus is applied to a soft body the pressure under which the stylus moves must be reduced below the limit of measurement, whereas hard bodies are only scratched by hard steel. Franz used both a steel and a diamond point, and endeavored to co-ordinate the results of the two by measuring the hardness of a given suitable body in terms of each stylus. It is true that the numbers obtained in the two series of experiments show a constant ratio (*cæt. par.*), but it does not follow that this would always be the case, and it is quite improbable for large intervals of hardness.

The second difficulty encountered is the dependence of the results of the sklerometer on the degree of sharpness of the marking stylus. None of the above papers touch upon this matter, nor would it be possible for them to estimate this effect. Yet it is quite obvious that the pencils of different apparatus can not have been identically sharpened, and that the pencil of the same apparatus will soon become blunted by continued use. Measurements into which this serious discrepancy necessarily enters cannot therefore be comparable among themselves. Finally, the modus operandi, the velocity of the moving stylus and the direction of the pressures are to be considered, and in some of the above papers hints relative to these points (motion, position, and inclination of pencil) are explicitly given. Barnes and Perlsin, however, first showed that the effect producible by varying the rate of motion of the stylus is so great as to be actually capable of inverting the data for hardness. Indeed, it has since become well known that the edge of a rapidly rotating, relatively soft disc is scarcely touched by a file or a lathe tool, and that if the motion be rapid enough, it is the tool which suffers most. Nor is this phenomenon to be referred to an effect of temperature, for it finds its full explanation in consideration with the rates of motion to which it is due. The hardest cast iron can be turned off with a steel tool at a velocity as high as 2 meters per second of the moving parts.

I am thus naturally led to the important question, whether the definition of hardness given by the sklerometer is correct in principle. I believe this is by no means the case. Quite aside from the serious practical difficulties which I have just summarized, it seems to me that hardness when determined by scratching is much too complex a conception to be used as a basis for the definition of the property. Compli-

cations are introduced by the motional phenomena, the lateral sheer which accompanies scratching, and in short by conditions which have nothing to do with hardness at all. It is easy to imagine how the method originated, for the tests must primarily have been made to find out whether the point was capable of puncturing the surface; but inasmuch as a puncture is not easily recognized, the passage was made from the point to the scratched line. The static method is, in fact, much older than the dynamic method of rating hardness. If therefore the static method is sufficient (and this will be shown below) to define hardness as a characteristic, independent, and clearly intelligible property of bodies, it is worse than superfluous to introduce processes by which the result can only be complicated. I do not mean to imply, of course, that the method of scratching has been fruitless. It has conquered its own ground. Thus, for instance, the gradual change of hardness at points within a given surface of a crystal is among the striking accomplishments within the reach of the method; but we can only arrive at a clear knowledge of the meaning of such observations after having solved the static problem of hardness and then noting the additional circumstances introduced, when we pass from the dent to the scratch. Regarded as practical method of quiet interpolation, scratching must retain a value which can only be enhanced by giving clear interpretations to the nature of the process, and the discrepancies which I have pointed out * need not then be apprehended.

Under the circumstances I am inclined to regard it as a step in the right direction, that the static method (static because motion is excluded) has recently again been taken up by a number of observers. Among these Crace-Calvert and Johnson, Hugueny,† Bottone,‡ and also Pfaff§ may be mentioned. In this class of apparatus a hard point is pressed or struck or drilled into the body to be measured, and the hardness is variously measured relative to given depths of penetration. This may be done by noting the weight necessary to sink the stylus or by the number of rotations of a definitely weighted needle (Pfaff's meso sklerometer). Again, the depth to which the stylus sinks for a given weight or even the time necessary to produce a given depth of impression have been used for registry. Here however it is clear at once that these methods are intrinsically different, and that far-fetched assumptions must be made relatively to the proportionality of hardness with the divers data obtained,—assumptions which need not even be approximately true. Furthermore, the body to which these different tests are applied is necessarily acted on in a state of strain, if not ac-

* Hugueny (see below), to whom similar considerations are due, takes account of three kinds of hardness, one "tangential" and the other two "normal."

† Hugueny: *Rech. Exp. sur la dureté des corps*, Paris, 1865. Cf. *Ber. de Strasb., Ges.*, 1865.

‡ Bottone: Sill. *Journ.*, 1873, p. 457; Pogg. *Ann.*, 1873, vol. 150, p. 644.

§ Pfaff: , *Münch. Ber.*, 1884, p. 255.

tually ruptured at the point of observation. At the time and place of measurement the body necessarily differs from the original body. Thus it appears that the results of such methods are not available.

With the object of corroborating the above remarks I will exhibit two typical series of data from the papers of Franz and of Pfaff (the latter obtained by means of the meso-sklerometer already referred to), choosing such substances as are sufficiently definite for comparison. In the first table the numbers for gypsum are made identical; in the second the same is done for corundum, the respective ratios being retained in both cases.

| Gypsum identically hard. | | | | Corundum identically hard. | | | |
|---|---|---|---|---|---|---|---|
| Body. | Franz. | Pfaff. | Ratio. | Body. | Franz. | Pfaff. | Ratio. |
| Gypsum | 6 | 6 | 1 | Corundum | 340 | 340 | 1.0 |
| Calcite | 36 | 8 | 4.5 | Topaz | 298 | 240 | 1.2 |
| Fluorite | 144 | 20 | 7 | Quartz | 228 | 160 | 1.4 |
| Apatite | 652 | 38 | 15 | Feldspar | 134 | 105 | 1.3 |
| Feldspar | 1,040 | 105 | 10 | Apatite | 84 | 38 | 2.2 |
| Quartz | 1,770 | 160 | 11 | Fluorite | 19 | 20 | 0.9 |
| Topaz | 2,230 | 240 | 9 | Calcite | 5 | 8 | 0.6 |
| Corundum | 2,650 | 340 | 8 | Gypsum | 1 | 6 | 0.2 |

Mere inspection of the table shows that the ratios of hardness* run as high as 15 in the first table, and fluctuate between 2.2 and 0.2 in the second.

It has already been stated that Hertz† investigated a definition of hardness which is mathematically exact, and which does not conflict with the prevailing notions of the quality. He replaces the indefinite point by a definite spherical surface; or, to state this more correctly, since the point is after all a spherical surface of very small radius, Hertz uses a stylus with a radius of curvature large enough to be measurable. Moreover, the material out of which the stylus (now a ball) is to be made, virtually does not at all enter into the problem. A body may therefore be tested for hardness by aid of a probe made of its own substance and the result is in no way dependent on vague properties of a foreign body. Finally, the body to be examined is not subjected to any permanent strain (set), but all operations are conducted within the limits of elasticity. The definition of hardness thus obtained takes the following general form: Hardness is the limiting elastic resistance (tenacity) of a body, in case of contact of one of its plane surfaces with the spherical surface of another body, thus all vagueness of conception has been removed, and hardness is tersely

* Similarly enormous variations of the ratios for metals may be obtained from the series of Bottone and Hugueny (Cu = 100, Ni = 104 to 58, Pt = 81 to 150, Pb = 42 to 9, etc).

† Hertz: *Verh. Berl. phys. Ges.*, 1882, p. 67; *Verh. d. Ver. z. F. d., Gewerbefl.*, 1882, p. 141.

classified with the allied properties encountered in case of tension, flexure, etc. It is of course necessary to go into further detail, in particular to determine how pressure is distributed and varies within the surface of contact, for upon these conditions the effects of stress and the resistance of the material will depend. The solution of this problem has enabled Hertz* to propound a fundamental principle. In his attempt to verify his theory experimentally Hertz was however much less successful, and as a consequence soon abandoned the work. The only data which he adduced refer to glass, and his results for hardness were:

| | Kg./mm². |
|---|---|
| Pressure of a hard steel lens against plate glass | 135 |
| Impact of two glass balls | 150 |
| Pressure of two thin glass rods | 190 |

Thus the data obtained are not satisfactorily constant. Moreover, my results show that not more than the third or fourth part of the discrepancies observed are referable to the material. Differences, therefore, necessarily remain. It would be inexpedient to attempt to account for them here, chiefly because the number of experiments made is much too small relatively to the conditions (form, material, stress, impact, etc.), under which the results were obtained. Nor has Hertz given a sufficiently detailed statement of the dimensions of the bodies examined.

## II. THEORY.

The pressureless contact between a sphere and a plane is a point. If pressure be applied at the center of the sphere, normally, both surfaces will change form near the point in question, until the strain has reached a given value. In other words, the sphere will be flattened and the plane curved, and the original point is now replaced by a surface of contact. I shall call this the impressed surface or area (Druchfläche). It is neither plane nor of the curvature of the sphere; but the radius will obviously lie somewhere between these limiting values, and will depend (*cæt. par.*) on the elastic properties of the two contiguous bodies. Furthermore, under the conditions stated, the impressed area is clearly circumscribed by a circle.

If pressure acting normally through the center of the sphere is increased the impressed surface will also increase in size, and the pressure is now brought to bear on a larger surface. But the strain to which the material is put will depend on the stress per unit of impressed surface, and we are thus led to inquire as to the law compatible with which the pressure per unit of area increases with the total pressure, for obviously both magnitudes must increase simultaneously. It is also easily seen that the relation between total pressure and pressure per unit of the impressed surface is closely allied with the relation of total

*Hertz: Crelle's *Journal*, 1882, vol. XCII, p. 156.

pressure to the increase of the impressed surface or area of contact. Now Hertz's theory shows the radius of the latter to increase proportionally to the cube root of the total pressure applied, and hence the impressed area will increase as the two-thirds power of total pressure. To this degree, therefore, the effect of total pressure is abortive; and in view of the enlargement of the impressed area stress per unit of area increases only as the cube root of the total stress. Furthermore, the manner in which pressure is distributed throughout the surface of contact is fully given by the theory. It is found that at any given time pressure decreases gradually from the center of the area towards its boundary where stress is necessarily zero, in accordance with the expression

$$\sqrt{1-\varkappa^2}$$

where $\varkappa$ is the fraction of the total radius of the impressed area by which any of its points is symmetrically located relatively to the center. The reference roughly made above to pressure per unit area is, therefore, of the nature of a mean value; and the maximum pressure at the center of area is related to the mean value here in question in the ratio of 3 to 2. Now if the total pressure at the center of the sphere is gradually increased, the maximum pressure per unit of area at the center of the impressed surface will also continually increase; and at a certain value one of the two bodies, or both (supposing them to be made of the same material), will necessarily reach the limits of elasticity. Evidence as to whether this has occurred or not is not far to seek; in a plastic body the strain will be permanent. There will, in other words, be an evidence of "set," for the parts affected fail to return to their original positions when the stress is relieved. Furthermore, in a brittle body, set will be actually accompanied by rupture at the parts too highly strained. We may therefore in all instances conclude as follows: The *least value of the (central) pressure per unit of area necessary to produce permanent set (or rupture) at the center of the impressed surface* is Hertz's datum for the hardness of the body under examination. In addition to the normal pressures every point of the area of contact is also actuated by lateral pressures, and it is quite feasible to obtain some general notion of their value. At the center of contact they are positive, *i. e.*, the body is uniformly compressed, whence it follows that in our method of testing a crack is not to be looked for here. The case is pronouncedly different near the boundary of the area, where the lateral stresses are all negative and of the nature of tensions; and since the loci of like stresses are circles concentric with the center of area, we may look for a circular line of rupture.

Thus far our considerations were only extended to a system of two given bodies in contact. The question arises how the condition will change if the original system is replaced by a second system differing

in any manner whatever from the former. The variations possible in such a case are twofold: (1) The spheres may have different radii, and (2) the bodies may have different elastic constants than those which obtained in the first experiment. The theory of the experiment shows, with regard to the first of these points, that (other things being equal) the radius of the impressed area is proportional to the cube root of the radius of the sphere, or that the area of the surface of contact varies as the two-thirds power of the radius. For the case of equal total pressures at the center of the latter, the pressure per unit of area, and hence also the maximum pressure in the impressed surface, must be proportional to the cube root of the curvatures of the sphere. To the extent, therefore, in which all reference is made to the stated central or maximum pressure (per unit of area), the data for limiting values of elastic resistance must be independent of the curvature of the impressing sphere. Hence the limiting value of total pressure is proportional to the square of the limiting or final radius of the area of contact; or, if the radius of the latter is expressed in terms of the total pressure and the radius of the sphere by aid of the above relations, then the value of total pressure, just sufficient to produce set, must increase with the square of the radius of the sphere. In regard to the second of the above queries, no special mention is expedient here. I will only remark that under conditions which are otherwise identical, the area of contact is expressible in terms of values of the elastic constants of the two contiguous bodies. To avoid this complication, I will at the outset confine myself to the state of things observed when both bodies are identical as to material. For this case the relations to be formulated admit of simple expressions.

It may be worth while, by way of recapitulation, to express the laws just ennunciated symbolically. Let $\rho$ be the radius of curvature of the sphere in millimeters, $p$ the total pressure applied at its center, $P$ its superior limit, *i. e.*, the value of $p$ at the time of occurrence of the permanent set. Let $p_1$ be the pressure per unit of area at the center of the impressed surface, *i. e.*, the maximum of pressure in kilograms per square millimeter, $P_1$ the superior limit of $p_1$, *i. e.*, the absolute hardness of the body. Let $d$ be the diameter of the area of contact (this quality is immediately given by observation, and is in so far preferable to the radius embodied in the above text), $D$ the superior limit of $d$, both in millimeters. Let $H$ be the true hardness, which, as will be shown in the sequel, differs slightly from the theoretic value $P_1$, $q$ an abbreviation of the quotient $p/d^3$, $Q$ its limiting value. Let $f$ be the area of contact, $F$ its limiting value, both in square millimeters. Finally, let $E$ be the modulus of elasticity of the material in kilograms per square millimeter, $\mu$ Poisson's coefficient, *i. e.*, the ratio of radial contraction to longitudinal extension, $E'$ an abbreviation of the quotient $E/(1-\mu^2)$. Brackets may serviceably be used to show that the quan-

tities inclosed are not expressed in the absolute units given, but in some convenient relative measure. Hence, the following formulæ are under consideration:

$$f=\frac{\pi}{4}d^2 \qquad F=\frac{\pi}{4}D^2$$

$$p_1=\frac{3}{2}\frac{p}{f}=\frac{6}{\pi}\frac{p}{d^2} \qquad P_1=\frac{3}{2}\frac{P}{F}=\frac{6}{\pi}\frac{P}{D^2}$$

for the same $\rho$ and $E^1$.

$$\frac{d}{\sqrt[3]{p}}=\text{const., and } \frac{d^3}{p}=\text{const., also } q=\text{const.,} \quad . \quad . \qquad (1).$$

This constant quantity must also be identical with $Q$. Hence, for the same $\rho$ and $E^1$, $p_1/\sqrt[3]{p}=$const. For a different value of $\rho$, but a given value of $E'$,

$$d/\sqrt[3]{p}\,\rho=\text{const., and } \rho q=\text{const.} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (2).$$

For different values of both $\rho$ and $E'$,

$$d=\sqrt[3]{\frac{12\,p\,\rho}{E^1}} \text{ and } D=\sqrt[3]{\frac{12\,P\,\rho}{E^1}}.$$

For different values of $\rho$ and a given value of $E'$,

$$P=\text{const., or}\left\{\begin{array}{l}\dfrac{P}{D^2}=\text{const.,}\\ \dfrac{P}{\rho^2}=\text{const.,}\\ \dfrac{D}{\rho}=\text{const.,}\end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3)$$

three equations which are merely different expression of a common inherent relation. Finally for given values of $\rho$ and $E'$, the theoretical hardness has the form

$$P_1=\frac{6}{\pi}\frac{P}{D^2}=\frac{1}{\pi}\sqrt[3]{\frac{3}{2}\frac{E'^2}{\rho^2}P}=\frac{6}{\pi}\sqrt[3]{P\,q^2}, \quad . \quad . \quad . \quad . \qquad (4)$$

and the elastic constant $E'$, the form

$$E'=12\,\rho\,q. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (5)$$

## III. METHOD.

It appears from the foregoing equations that to compute hardness by aid of the phenomenon of contact between a sphere and a plane of a given body the total pressure under which contact takes place is to be increased up to the elastic limits. The time of yielding being

sharply marked by the occurrence of either permanent set or of rupture at the area of contact, it is merely necessary to measure the total pressure $P$ and the diameter of the impressed area $D$ for the time in question. The first of the equations (4) then leads at once to the value of theoretical hardness. In the interest of accurate work, however, it is unfortunate that the two quantities $P$ and $D$ can be measured but once. It is therefore desirable to introduce some variation of method at least for $D$, for $P$ does not admit of a second expression. For this purpose the other two equations given under (4) are available. One of them (the second in order) premises a knowledge of both $E^1$ and $\rho$, as well as of $P$. Now, although $\rho$ may be considered sufficiently given by the radius of the spherical stylus, $E^1$, on the other hand, would have to be taken from tabulated data of $E$ and $\mu$, or be preliminarily measured by aid of a special piece of the given body. Neither of these alternatives is acceptable, while $\mu$ is known to vary even with insignificant structural differences of the given substance, and can not even be considered constant for different parts of it. On the other hand, the third in order of the equations (4) is useful in every particular. Based as it is on the values of $P$ and $q=p/d^3$ only, its availability is enhanced by the fact that the $q$ is constant, and can therefore be taken from a whole series of measurements of increasing $p$. Far from being dependent on a single measurement, therefore, the observer is at liberty to reject the limiting value $Q$ altogether; for if it should differ from the other values $q$, an explanation is readily found in the fact that $Q$ is measured when "set" has already occurred. The additional labor involved in a step-for-step increase of $P$ is of no moment, seeing that such procedure is under all circumstances necessary. For the limits of elasticity must be gradually approached and not overstepped.

I have already stated that brittle bodies present a case of easy observation, for here set is accompanied by rupture. Only in rare instances is this criterion preceded by a visible indentation without break of continuity, and a puncture of this kind can usually be referred to a lack of homogeneity in the material or to anomalies of brittleness. Hence I found it advantageous to begin my work with brittle bodies, and the general method was devised with special reference to the fact that nearly all such bodies, in particular the glasses and the greater number of crystals, are more or less transparent.

The spheres in these experiments are suitably ground in the form of a plano-convex lense, with a radii of curvature of 1 to 30 millimeters. The plane surface is preferably a plate, about 11.6 millimeters in diameter and 8 millimeters thick. The thickness is purposely chosen of the same order of magnitude as the diameter, in order that any discrepancy of the nature of flexure may be excluded from the start. The plate is fixed in position while the lense is free to move up and down, and pressure is suitably transmitted by a lever actuated by a set of weights. The area of contact and the occurrence of the indentation are

to be observed, of course, for an invariable position of the plate and lens with reference to the horizontal, and the measurement is made through a microscope with its line of sight normal to the plate, seeing that the lengths to be taken are small. In the field of the microscope the impressed area appears in form of a dark circular spot, which, together with the rings surrounding it, presents a case of interference. I shall show that even the diameters of the rings are available for measurement. Further particulars however are best discussed in connection with the apparatus.

## IV. APPARATUS.

Through the kind permission of Prof. Abbe, the apparatus was constructed in the workshop of M. Zeis, of Jena, and I desire in this place gratefully to acknowledge the suggestions received from my colleagues, in particular from Prof. Abbe, during the course of its construction. Fig. 1 shows the completed instrument in sectional elevation, nonessential parts having been withdrawn for clearness. It is put together massively, so as to withstand the powerful stresses which are to be brought to bear on it, and it is firmly planted on a pier in one of the vaults of the university. Ample provision is made to guard

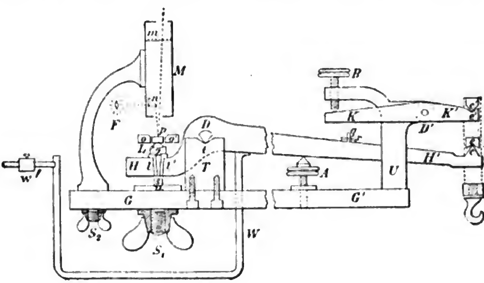


FIG. 1.

against tremors. The cast-iron bedplate $G$ $G'$ is T-shaped in cross section, 73cm long and 7.5cm wide, and a central gutter runs from end to end.

The support $T$, screwed to the bedplate, is provided above by a re-entrance $t$, in which the knife edge $D$, around which the wrought-iron lever $H$ $H'$ is free to turn, is suitably adjusted. The short arm of $H$ $H'$ terminates in a ring-shaped expansion $l$ $l'$, at a mean horizontal distance of about 5cm from the axis $D$. In the conical perforation in $l$ $l'$ a plug $Z$ fits snugly and the lens $L$ is attached to the top of $Z$. The other arm of $HH'$ is about ten times as long as the short arm, and ends in the knife edge $c$. The glass plate $p$, to be tested, is attached to the upper perforated plate $o$ $o'$, secured by means of a pillared arrangement, of

which $s$ is alone visible in the figure. The plate $o\ o'$ is about 1.6$^{cm}$ thick, and its lower face is flush with the corresponding face of $p$. The whole case can be moved in the gutter of the bedplate, and clamped in any position by aid of the strong screw $S_1$. It is, therefore, easily possible to place a part of the glass plate $p$ opposite the vertex of the test lens $L$. The microscope $M$ is similarly movable, and the clamp screw $S_2$ admits of an adjustment relative to the point of contact to be observed. It is expedient to fasten the lens $L$ to the top face of the plug $Z$ with cement. The plate $p$, however, exactly fits the hole in $o\ o'$, and adjustably hinged stops prevent it from falling out. The microscope $M$ contains an ocular micrometer $m$, and since illumination from below is clearly impossible, the light of a lateral gas flame $F$ is reflected downward by the prism $n$, small enough to only half fill the right section of the tube. After impinging on the lens and plate, the rays are reflected upward through the open half of the tube and the micrometer $m$, finally reaching the eye of the observer. The long arm of the lever $H'$ abuts against the screw $A$, and its play may, therefore, be stopped short high enough to prevent all premature contact between the test lens and plate. When $A$ is screwed down, moreover, the long arm would much overbalance the weight of the short arm $H$. To obviate this a duplicate wrought-iron arm $W$ has been added, along the free end of which a weight $w'$ may be adjusted to counterpoise the long arm.

The form given to $W$ is such that the center of gravity of the lever as a whole is not seriously depressed, and a balance sufficiently sensitive for the present purposes is thus secured. The counterpoise $w'$ is to be fixed so that the position of equilibrium may leave a little space between the test lens and the plate. Little rings $r$ surrounding the pin $q$ are then added until an almost pressureless contact is initially obtained. However slight, a true contact is always easily recognized by the passage of the colored interference rings into a black spot. In order that this initial contact may easily be reproduced, and the progress of an experiment may at any time be checked, a second lever $K\ K'$, supported by the pillar $U$ near the end of the bedplate, is at hand. A stirrup $R$, from the hook of which scale pans of different sizes may be suspended, suitably connects both levers (knife edges $c$ and $c'$, as shown in figure). By a play of the screw $B$ the $K$ end of the lever may be depressed and the $K'$ arm raised. In this way the stirrup is lifted off of the knife edge $c$, and the lever $H'$ is therefore unloaded. Conversely an opposite play of the thumbscrew $B$ depresses $K'$, and the load is therefore transferred from the knife edge $c'$ to the knife edge $c$, whereby the lever is loaded, gradually or expeditiously, at pleasure. These adjustments enable the observer to carry out the necessary operations smoothly, and without any danger of jarring or striking the parts to be tested together. The elasticity of the long lever, moreover, is in favor of a perfectly uniform and slow intensification of the pressure to be applied. It was my plan to return to the

pressureless contact, after the effect of each of the successive step loads had been brought to bear, and thus the load corresponding to the occurrence if an indentation in $p$ was indicated with certainty (see below).

## V. GENERAL REMARKS ON THE OBSERVATIONS.

Apart from special methods of research the general plan of the experiments was as follows: The plate and lens are first carefully to be freed from dust, grease, moisture, etc., and then to be screwed into their respective places at the center of the plate $o\ o'$ and at the top of the plug $Z$ as securely as possible. The screw stop $A$ is lifted high enough that the plate case $o\ o\ s$ may be pushed over the lens without danger of touching it. Then the miscroscope is adjusted and all parts eventually clamped in place with reference to the particular part of the glass plate where the test is to be made. It is expedient to clamp $S_1$ first, and then to clamp $S_2$ in such a way that the point in question may occupy the middle of the field of view. During these operations it will have been necessary to gradually lower the stop $A$, though not quite as far as the position of contact. This is best done when the microscope is fixed. Under these circumstances, however, if the lever $H\ H'$ should not swing freely, the long arm $H'$ is presumably too heavy, and $w'$ must be moved further outward along the slide (a little weight $r$ being added if need be) until the pressureless contact occurs, when the lever swings freely. This adjustment may actually be made to an accuracy of about 1 gram, a degree of sensitiveness far in excess of the demands.

The load is now applied, beginning with the stirrup $R$ as the first centerpoise. The screw $B$, which has thus far stood low, is raised until the load is carried simultaneously by $c'$ and $c$. $B$ is then raised *very gradually*, however, until the load $R$ has been quite transferred from $K\ K'$ to $H\ H'$, the observer availing himself meanwhile of the elasticity of the long lever. Indeed it is possible to raise $B$ so uniformly that the area of the spot seen in the field of the microscope scarcely enlarges, so that the strain is imparted to the plate at a very slowly increasing rate. Should the weight of $R$ ($227^g$) be regarded too large as a first step, smaller weights may be attached with a string. Having read off the first diameter of the ring and noted the first load, the large lever is unloaded and the scale pan attached to the hook of the stirrup $R$. Then the lever $H\ H'$ is again loaded in the manner described, and the value of the diameter of the spot read off for the second load. This process is repeated as often as desirable, with the single additional precaution that when the limits of elasticity are being gradually approached (determined from preliminary trials), the weights are added to the scale pan in smaller steps than at the outset. Eventually, therefore, the values $P$ and $D$ (load and spot diameter) which correspond to rupture are obtained. The method described has many advantages;

the observer can proceed with his work smoothly and without annoying accidents; for the weights are added by a method of manipulation which is wholly without disturbing influence on the test plates, etc.

Theoretically, however, the method is not altogether free from objections, inasmuch as the impressed surface is continually loaded and unloaded, and therefore put through a series of increasing cyclic strains, until the final point of rupture is reached. For this reason I made special sets of measurements, in which the loads were added gradually with every available precaution, of course, but *without* passing back to the pressureless contact at the end of each step. Near the end of the operation I carefully charged the scale pan with sand, pouring it in so gradually that the increase of the load was practically continuous. These experiments led to some interesting subsidiary facts; but as they did not change the chief issue with which we are now concerned, I need only accentuate the remarks already made, that it is never permissible to increase the load quickly, not even at the beginning of the work when the loads are all small. In all such cases rupture is liable to occur prematurely, and the discrepancy is frequently of serious moment.

In addition to the corresponding values of $p$ and $d$, $P$ and $D$, other quantities were usually observed, such, for instance, as would be necessary for corrections, etc., and for the ultimate purposes of this research. I always noted the diameter of the Newton rings, as well as the diameter of the locus of rupture. As to the latter I may here remark (definite researches will be published elsewhere) that in case of isotropic media it is in fact a circle and concentric with the area of contact; yet it does not coincide with limits of this area, but surrounds it in accordance with a well-defined law. For crystals the locus of rupture is not circular, but an intermediate figure between a circle and a polygon (hexagon, rhombus, triangle, etc.).

A few words on the diameter of the spot are in place here because of their bearing on the accuracy of measurement. I found by trial that the demarcation was sharpest in case of faint illumination, for in this case the light was not annoyingly reflected from the upper face of the test plate. In general this definition varies in marked degree in different experiments, and even different parts of the edge of a given spot are not equally distinct. Usually, however, 0.7 scale part of the micrometer is guaranteed.

From an economical standpoint it is fortunate that a single plate and lens will outlast many experiments, certainly as many as are necessary for obtaining a sharp average of results. The lens is not usually affected, but retains its even surface indefinitely. The plate is large enough for upwards of 30 or 40 fields of rupture on each of its sides. It is advisable to rule the side of the plate which is not to be used with a set of rectangular cross-section lines. Curiously enough, the divers circles of rupture do not seem to interfere with each other, even when they are nearly contiguous, or when the loci actually intersect. I found

by trial that the values obtained in the last instance were more abnormal, but I did not use them. Fig. 2, supplied to corroborate these statements, represents the available part of the plate. It contains fully 28 indentations, varying in size because lenses of different curvature were used, but it appears at a glance that there is room for many more experiments.

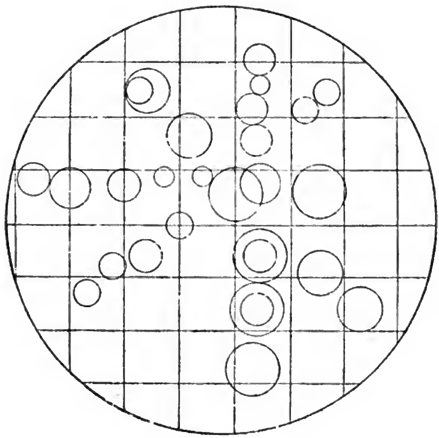

FIG. 2.

## VI. THE CONSTANTS AND SOURCES OF ERROR.

The two chief constants of the apparatus are the scale value of the ocular micrometer and the ratio of the arms of the prime lever. The former was obtained in the usual way by comparing it with an objective micrometer. In my final and most accurate comparisons a tenth millimeter scale was inserted in place of the plate $p$. Thus I found

$$27 \text{ scale parts} = 1^{\text{mm}}$$

with a deviation near the edges of the field presently to be discussed. In view of the form of the lever the ratio of the arms could not have been measured accurately by a direct method. Hence, I replace the plug $Z$ by another containing a pin, on which a strong scale pan hanging in the main below the bedplate $G\ G'$ could be pivoted. Observations made for equilibrium between the new pan and the stirrup $R$ (weights being suitably added to the former) showed the ratio in question to $V = 9.8$, with a probable error of $\pm$ 0.01, *i. e.*, only about a tenth per cent of the value of $V$. It follows, therefore, that all measurements in terms of the ocular micrometer are to be divided by 27, and

the observed load at the end of the lever (including of course the weight both of the stirrup $R$ and the pan) is to be multiplied by 9.8. Thus the values of spot diameter and total pressure are reduced to absolute units.

The third class of constants are the lens curvatures, purposely varied in different experiments. I did not attempt to find them, however, for I was able to avail myself of the values of the mechanician in charge, who, in addition to the chief datum, also supplied me with the errors probably made in their manufacture. These errors never exceeded $0.1^{mm}$, and were even smaller than this for smaller curvatures.

Another important question may be alluded to here. It does not follow at once that the diameter of the black spot measured in the field of the telescope actually coincides with the area of contact. The question relative to the correction to be applied is to be looked at from four points of view: (1) It is known that in case of Newton's rings, light is not only extinguished throughout the area of contact, but throughout a somewhat wider margin to a point at which the vertical distance between plate and lens is about $\frac{1}{6}$ wave length (say), depending on the intensity of the illumination. The spot is therefore to this extent larger than the area of contact. Now, it would be possible to compute this correction from the data theoretically given for the curvature of the area of contact in a way sufficient for all possible cases; and this has been done. It is much simpler, however, and more free from assumptions which need not be detailed here, to refer such measurements to the first of the rings surrounding the black spot. For the position of the ring is such that the vertical distance between plate and lens is necessarily $\frac{1}{2}$ wave length. Now, since the area of contact is always very small, the curvature of contiguous parts may be neglected. Hence the correction to be applied [deducted] is $\frac{1}{3}$ of the distance of the first ring from the edge of the spot, meaning, of course, the *true* edge. In other words, the correction is one half the distance, $\epsilon$, between the first ring and the apparent edge of the spot; and since this correction ($\frac{1}{2}\epsilon$) is to be deducted from both ends of the diameter $d$, the full correction is $\epsilon$, or the true diameter of the area of contact is $d-\epsilon$. It is advisable, therefore (other considerations will appear below), to construct a table in which for any given substance the correction may be taken at once as a function of the pressure applied and the curvature of the lens used. For practical purposes, moreover, an approximate table, in which the correction is mapped out as a function of spot-diameter and lens-curvature, $\rho_1$, will in most cases be sufficient, no matter what the substance may be. Such a table may here be inserted, spot-diameters, $d$, being given in scale parts, and the correction in $\frac{1}{10}$ scale parts of the ocular micrometer.

| | $p = 1$ | 3 | 4 | 5 | 10 | 12 | 15 | 30 |
|---|---|---|---|---|---|---|---|---|
| $d = 5$ | 1 | 3 | 4 | 4 | 6 | 7 | 8 | 12 |
| 10 | ...... | 2 | 2 | 3 | 4 | 5 | 6 | 10 |
| 15 | ...... | 1 | 1 | 2 | 3 | 4 | 6 | 9 |
| 20 | ...... | ...... | 1 | 2 | 3 | 3 | 5 | 8 |
| 25 | ...... | ...... | ...... | 1 | 2 | 3 | 4 | 7 |
| 30 | ...... | ...... | ...... | 1 | 2 | 2 | 3 | 6 |
| 35 | ...... | ...... | ...... | ...... | 1 | 2 | 3 | 5 |

(2) The astigmatic aberration of the image observed through the plate is next to be considered. In view of the small angular deviation of the lines of sight, the error in question will never exceed one-tenth per cent of the observed value, unless, indeed, the observations are made near the circumference of the field of view. This is quite unnecessary and should not be done.

(3) Another negligible error is introduced by the fact that the observed spot is a horizontal projection of the curved area of contact. Even in the case of my most convex lenses and the highest pressure admissible, the effect of the difference of area of the actual surface and its projection will not exceed 2 in 1,000.

(4) Finally the flexure of the test plate $p$, which under the circumstances is converted into a concave lens, may be adduced. A correction of this kind would be appreciable, if the object to be observed were situated at an appreciable distance below the lens. This state of things can not be at once dismissed, for the locus of the circumference of the spot is at a place where the plate and the lens no longer touch each other, as has just been indicated. In other words, the question contemplates the actual position of the locus or seat of interference. Divers experiments which I made with special reference to this discrepancy proved however that the present source of error is not of greater moment than the preceding.

## VII. THE THEORY TESTED.

The materials to which I confined my present experiments were glass and quartz. The glass was obtained from the well-known house of Schott & Gen, and the three samples furnished were marked I (rather soft), II (of mean hardness), and III (rather hard). The mere fact that I was thus able to avail myself of three degrees of hardness of one and the same substance lent a peculiar interest to the tests, for the differences of hardness in question could not in any case be very marked, and the tests would therefore contain an immediate indication of the sensitiveness of my method. In addition to these substances I also worked with a plate of quartz (IV) cut at right angles to the crystallographic axis. Here, as well as in the case of the glass (I, II, III), the lens and plate were cut from one and the same substance in each case.

Preliminary optical work showed that the departure from homogenity throughout the mass of glass examined was nearly inappreciable, and the same was true of the given faces of the quartz appliances. Had it not been the case, the tests themselves would, in the course of the work, have indicated deficient isotropy, seeing that both the position or the shape of the lines of rupture depend on these conditions. Such results were indeed actually obtained in certain experiments which I made with this especial end in view, but with which I will not further detain the reader, for another question, and an important one, has since loomed into view and must now be answered. The theory sketched above makes mention only of isotropic media, and thus it is not warrantable to apply it to crystals.

In a measure this is true, but it must be noticed that in the first of the equations (4) only the numerical coefficient is influenced by æolotropy, and if equations (1) and (2) can be proved to hold for the crystalline body empirically, then the last of the equations (4) can be wrong only as to its coefficient. Furthermore, the uncertainty can be tested by means of the equation (3), as compared with the second of the equations (4), to a very small margin of uncertainty, by inserting known values of the elastic constant $E'$. Aside from this an interpretation of the coefficient in question shows that it is necessarily inclosed within narrow limits. There is still another point of view. Hertz's theory is true for elliptical contact surfaces quite as much as for spherical surfaces, from the nature of the reasoning employed; and even in the more general case (ellipsoid) the numerical factor in questions turns out to be 3/2. If therefore the latter is independent of differences of direction considered geometrically, it will also be independent of the elastic assymmetry, a consideration, it is true, which applies primarily for lines lying in the plane surfurce of the plate, but does not apply to the normal dimensions or depths.

I am bound to acknowledge, therefore, that the data obtained with crystals are possibly not as accurate as the corresponding data for isotropic substances. This curious divergence in the behavior of crystals and glasses is borne out by the following qualitative result: Whereas impressed area and the line of rupture of an isotropic body is always a circular, only the impressed area retains this figure for quartz, while the lines of rupture is a figure midway between a circle and a hexagon. I will return to this matter elsewhere. The radii of curvature of the lenses used were widely varied, and the values 1, 3, 4, 5, 10, 12, 15, and 30 $^{mm}$. enter the following experiments, the first and last, however, only in special work. If the radius is too small there is obvious difficulty in measuring the area of contact. Large radii, on the other hand, are equally unsatisfactory. The initial point-contact is not always attainable in this case, while the stress which must ultimately be brought to bear is a serious tax on the apparatus. Again,

the circles of rupture are so large that for a given plate relatively few tests can be made.

My first measurements, made with the sole object of verifying Hertz's theory, bear directly on the truth or the degree of approximation of the equations (1) (2) (3) of section 2. Not until this was done was it warrantable to proceed with equations (4) and (5) for the measurement of $P_1$ and $E^1$. (1) To test the equation, (1), $q=$ const., or $p/d^3=$ const., many measurements were made for each of the four samples enumerated, and for increasing values of pressure. Here a few results selected at random from my notebook may be exhibited.

| Glass II, $\rho=10$. | | | Quartz $\rho=12$. | | | Glass III, $\rho=4$. | | |
|---|---|---|---|---|---|---|---|---|
| [$p$]. | [$d$]. | 1,000 [$q$]. | [$p$]. | [$d$]. | 1,000 [$q$]. | [$p$]. | [$d$]. | 1,000 [$q$]. |
| 227 | 8.9 | 321 | 754 | 12.4 | 396 | 854 | 10.0 | 854 |
| 354 | 10.5 | 306 | 1,254 | 15.0 | 371 | 1,154 | 11.0 | 866 |
| 554 | 12.1 | 313 | 1,677 | 17.0 | 341 | 1,754 | 12.6 | 877 |
| 754 | 13.5 | 307 | 2,677 | 19.6 | 356 | 2,454 | 14.3 | 876 |
| 954 | 14.6 | 306 | 3,177 | 20.5 | 369 | 2,479 | 14.4 | 866 |
| 1,354 | 16.4 | 307 | 3,677 | 21.6 | 368 | | | |
| 1,554 | 17.1 | 311 | 4,390 | 23.0 | 359 | | | |
| 1,677 | 18.0 | 288 | 4,800 | 23.7 | 361 | | | |
| 1,925 | 18.7 | 294 | 4,887 | 23.9 | 357 | | | |
| 3,177 | 22.1 | 294 | | | | | | |
| 3,225 | 22.2 | 295 | | | | | | |
| 3,725 | 23.4 | 291 | | | | | | |
| 4,547 | 24.6 | 306 | | | | | | |

It appears at a glance that in the third series $q$ is constant and that the same is true as a first approximation in the first and second series. Closer scrutiny of the data reveals a gradual but slight decrease of $q$ in the latter cases, arbitrary fluctuations being allowed for. Thus in the first series the average $q$ for the first seven observations is 310, and for the last six 295; in the second series similarly the mean $q$ for the first five and the last four observations is 367 and 361, repectively. This discrepancy is accounted for by equation (5), and indicates a corresponding decrease of $E^1$, that is either a gradual diminution of the modules $E$, or of Poisson's ratio. Both conditions may plausibly be assumed. But since the observed march is insignificant or even quite absent in some of my series, it may justifiably be neglected. I shall therefore take $q=$const. throughout my work. With this understanding the probable errors of $q$ in the above table may be computed and appear as follows:

$$[q]=0.3028\pm 0.0016;\ [q]=0.3643\pm 0.0031;\ [q]=0.868\pm 0.003,$$

so that the mean value of $q$ for the experiments is correct to about one-half per cent and the error of the quartz series does not exceed 1 per cent. By repeating the above work a number of times the attain-

able accuracy is further increased. Values of $q$ obtained in this way for different plates and different lenses of the same material and radius in each case show larger differences than the foregoing analysis has made probable. Hence it is reasonable to suppose that the different samples really differ as to elasticity, although the differences and the probable errors are surprisingly small.

*Glass I, values of q.*

| $\rho=1$ | $\pm$ | $\rho=1$ | $\pm$ | $\rho=12$ | $\pm$ | $\rho=4$ | $\pm$ |
|---|---|---|---|---|---|---|---|
| 468 | .......... | 455 | .......... | 122.1 | 2.7 | 39.4 | 0.2 |
| 429 | .......... | 455 | .......... | 110.6 | 1.1 | 38.3 | 0.3 |
| 502 | .......... | 476 | .......... | 115.7 | 1.3 | 38.7 | 0.3 |
| 454 | .......... | 456 | .......... | 117.7 | 2.6 | 40.0 | 0.1 |
| 429 | .......... | 482 | .......... | | | | |
| 442 | .......... | 449 | .......... | | | | |
| 505 | .......... | 476 | .......... | | | | |
| 448 | .......... | | | | | | |
| Mean results ...... | | 465 | 4 | 116.5 | 1.6 | 39.1 | 0.25 |

*Glass II, values of q.*

| $\rho=3.$ | $\pm$ | $\rho=5.$ | $\pm$ | $\rho=10.$ | $\pm$ | $\rho=15.$ | $\pm$ |
|---|---|---|---|---|---|---|---|
| 202.6 | 1.9 | 118.9 | 1.0 | 58.5 | 1.5 | 36.7 | 0.9 |
| 196.3 | 3.4 | 111.6 | 3.0 | 57.2 | 1.3 | 37.3 | 0.4 |
| 190.6 | 2.8 | 112.2 | 3.1 | 58.5 | .......... | 39.0 | 1.6 |
| 195.7 | 4.7 | 115.0 | 2.6 | 59.7 | 1.5 | 39.2 | 0.7 |
| 196.3 | 1.9 | 111.3 | 1.5 | 59.3 | 0.9 | .......... | .......... |
| .......... | .......... | 116.0 | 2.4 | 59.7 | .......... | .......... | .......... |
| .......... | .......... | 112.7 | 3.8 | 59.6 | 2.2 | .......... | .......... |
| .......... | .......... | 117.1 | 0.7 | 55.3 | 1.1 | .......... | .......... |
| .......... | .......... | 120.0 | 0.9 | 56.0 | 1.3 | .......... | .......... |
| 195.4 | 1.2 | 114.9 | 0.7 | 58.3 | 0.4 | 38.3 | 0.4 |

*Glass III, values of q.*

| $\rho=4.$ | | $\rho=12.$ | $\pm$ | $\rho=30.$ | $\pm$ |
|---|---|---|---|---|---|
| 160 | .......... | 52.2 | .......... | 22.0 | 0.1 |
| 167 | .......... | 53.1 | .......... | 21.7 | 0.0 |
| 151 | .......... | 52.8 | .......... | 21.7 | 0.1 |
| 168 | .......... | 53.1 | .......... | 21.6 | 0.1 |
| 167 | .......... | 53.3 | .......... | 21.9 | 0.1 |
| 162 | .......... | .......... | .......... | 22.2 | 0.1 |
| 162.5 | 1.7 | 53.0 | 0.2 | 21.85 | 0.05 |

*Quartz, values of q.*

| $\rho=1$ | $\pm$ | $\rho=4$ | $\pm$ | $\rho=12$ | $\pm$ | $\rho=12$ | $\pm$ |
|---|---|---|---|---|---|---|---|
| 823 | ........ | 218 | ........ | 70.5 | ........ | 71.5 | ........ |
| 848 | ........ | 208 | ........ | 69.2 | ........ | 70.9 | ........ |
| 853 | ........ | 215 | ........ | 71.9 | ........ | 69.8 | ........ |
| 854 | ........ | 210 | ........ | 67.3 | ........ | 70.5 | ........ |
| 854 | ........ | 210 | ........ | 70.7 | ........ | 72.0 | ........ |
| 846 | 4 | 212.2 | 1.2 | Mean value = | | 70.4 | 0.9 |

(2) The following data are sufficient to verify equation (2), viz. $\rho q =$ const.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Glass I ... | $\rho=$ | 1 | 4 | 12 | ........ | | |
| | $q=$ | 463 | 116.5 | 39.1 | ........ | $\rho q$ | 466 ± 1 |
| | $\rho q=$ | 463 | 466 | 469 | ........ | | |
| Glass II .. | $\rho=$ | 3 | 5 | 10 | 15 | | |
| | $q=$ | 195.4 | 114.9 | 58.3 | 38.3 | $\rho q$ | 580 ± 2 |
| | $\rho q=$ | 586 | 575 | 583 | 575 | | |
| Glass III . | $\rho=$ | 4 | 12 | 30 | ........ | | |
| | $q=$ | 162.5 | 53.0 | 21.8 | ........ | $\rho q$ | 647 ± 4 |
| | $\rho q=$ | 650 | 636 | 654 | ........ | | |
| Quartz.... | $\rho=$ | 1 | 4 | 12 | ........ | | |
| | $q=$ | 846 | 212.2 | 70.4 | ........ | $\rho q=$ | 847 ± 1 |
| | $\rho q=$ | 846 | 849 | 845 | ........ | | |

(3) It is now only necessary to prove the equations (3). The data for $P$ vary between 4 and 140 kilograms, an interval which in comparison with the small areas of contact encountered is strikingly large. In the case of different experiments made under the same conditions, *i. e.*, for values all corresponding to the same material and the same lens curvature, $P$ varies pronouncedly, as the following example shows. The series is again chosen at random and represents an unfavorable case, for the probable error of the mean result is fully $3\frac{1}{2}$ per cent.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Glass III | $P=$ | 17.2 | 24.3 | 18.1 | 24.0 | 21.2 | 19.2 | 18.2 |
| $\rho=4$ | $D=$ | 0.47 | 0.53 | 0.50 | 0.50 | 0.49 | 0.48 | 0.48 |

Mean value, $P=20.3 \pm 0.7$.

Now, it is to be observed (1) that at large value of $P$ is usually correlated with a large value of $D$, and therefore also corresponds to a smaller $q$, thus the fluctuations are in part rectified; (2) that in the final equation (4) the cube root of $P$ only enters, so that all errors are reduced as 1 to 3.

Quite an unexpected result is reached, however, when the data for different lens curvatures are compared. The equations (3) are not corroborated, not even approximately, though it would not be difficult to find a corrected term. Thus, for instance, in case of the glass II the data are:

| $\rho$ = | 3 | 5 | 10 | 15 |
|---|---|---|---|---|
| $P : D^2$ = | 81.7 | 67.0 | 56.6 | 49.8 |
| $P : \rho^2$ = | 1.64 | 0.96 | 0.50 | 0.32 |
| $D : \rho$ = | 0.142 | 0.119 | 0.094 | 0.080 |

All of which relations, instead of being constant, appreciably decrease.

This may be expressed as follows: *The pressure per unit of area which just produces a line of rupture* in the surface of a given plate of a given body, is not always the same; the said pressure *increases in proportion as the test lens is more convex or the area of contact smaller.* A further statement to the same effect may be made by indicating that the total pressure just sufficient to produce a line of rupture is not proportional to the square of the lens curvature; or again that the diameter of the impressed area when rupture just occurs is not directly proportional to the radius of the lens, seeing that both quantities increase at a retarded rate. Mere inspection of the above table shows, however, that the values of the second row ($P : \rho^2$) decrease at the rate in which the values $\rho$ increase, and the same observation applies to the other rows. Hence it follows that the relations theoretically deduced above are to be replaced by empirical relations such that (1) $P$ is not proportional to $D^2$, but to $D^{3/2}$, (2) $P$ is not proportional to $\rho^2$, but to $\rho$; (3) not $D$, but $D^{3/2}$ is proportional to $\rho$.

In how far these inferences are actually borne out by experiment is shown by the following summary:

| $\rho$ = | 3. | 5. | 10. | 15. | Mean values. |
|---|---|---|---|---|---|
| $P : D^{3/2}$ | 53.4 | 52.0 | 54.8 | 54.5 | 53.7 ± 0.4 |
| $P : \rho$ = | 4.93 | 4.78 | 5.04 | 4.80 | 4.89 ± 0.04 |
| $D^{3/2} : \rho$ = | 0.092 | 0.092 | 0.092 | 0.088 | 0.091 ± 0.001 |

The probable errors are throughout only about 1 per cent.

For the other plates these relations were also applicable. In these cases, however, only two values of $\rho$ (4 and 12 millimeters) were available, so that the test is not very cogent. I therefore had a new plate and lens made out of each of the samples of soft glass I and of quartz, selecting the radius in such a way that the impressions of the stylus approach the effect produced by a point or needle. A small radius also seemed preferable from the following ulterior considerations: If the value of the pressure per unit of area which just produces rupture is a function of the radius of the lens, then the value $\rho = 1$ (millimeter) as compared with the above radii, must possess the particular importance of a unit. Experiments made with these small and highly convex lenses, cannot of course lead to as great a regularity of data as were obtained in many of the above cases; but the mean result is none

the less pronouncedly in harmony with the relations just adduced. This appears in the following summary:

| | Values. | $\rho =$ | 1 | 4 | 12 | Mean values. |
|---|---|---|---|---|---|---|
| Glass I .... | Theoretically constant. | $P/D =$ | 111.1 | 71.0 | 48.1 | ................ |
| | | $P/\rho^2$ | 6.37 | 1.65 | 0.53 | ................ |
| | | $D/\rho =$ | 0.240 | 0.153 | 0.103 | ................ |
| Glass I .... | Found to be constant. | $P/D^{1/2} =$ | 54.4 | 55.4 | 53.5 | 54.4 $\pm 0.3$ |
| | | $P/\rho =$ | 6.37 | 6.59 | 6.35 | 6.44 $\pm 0.5$ |
| | | $D^{3/2}/\rho =$ | 0.117 | 0.119 | 0.119 | 0.18 $\pm 0.001$ |
| Quartz .... | Theoretically constant. | $P/D^2$ | 199.8 | 95.2 | 66.9 | ................ |
| | | $P/\rho^2 =$ | 50.5 | 1.31 | 0.42 | ................ |
| | | $D/\rho =$ | 0.183 | 0.118 | 0.079 | ................ |
| Quartz .... | Found to be constant. | $P/D^{3/2} =$ | 64.3 | 65.8 | 65.2 | 65.1 $\pm 0.3$ |
| | | $P/\rho =$ | 50.5 | 52.2 | 50.5 | 5.11 $\pm 0.04$ |
| | | $D^{3/2}\rho =$ | 0.0786 | 0.0793 | 0.0775 | 0.0785 $\pm 0.0004$ |

Here, as in the above case, the probable errors are between $\frac{1}{2}$ and 1 per cent.

On the basis of these results it follows, therefore, that if hardness be computed by the last of the equations (4), the Hertzian values, $P_1$, will vary with $\rho$. If, however, these data ($P_1$) are multiplied by $\sqrt{D}$, or, more conveniently, by 3 $\sqrt{\rho}$, then the new values of hardness are constant qualities, irrespective of the curvature of the stylus used. In general, furthermore, the theoretical premises have been corroborated by experiment to a remarkably close degree of accordance; only in one point (and this happens to be the most important deduction) is there a wide divergence between predictions of the theory and the facts. Inasmuch as the disagreement evidences a well-defined law, it is worth while to examine the conditions under which the theory applies.

(1) Hertz supposes the area of contact to be small relatively to the spherical surface. In the above experiments, however, it is quite doubtful whether this can at once be assumed in all cases. Indeed, the ratios of the limiting radius of the impressed area $R$ and the lens radius $\rho$ reach values as high as 1 : 11, and they can not be at once dismissed. We are thus led to inquire in how far the theoretical statements, relatively to pressure direction and pressure components, curvatures and area of the impressed surface, are affected by the large values $R/\rho$ specified. I have done this and find, in a way which has already been suggested in the above text, that the theory still holds to a degree quite within the errors of experiment, at least in the majority of observations. The fixed values of $q$, moreover, is compatible with this result, for in the case of increasing loads $q$ is pronouncedly constant when $\rho$ is smallest.

(2) Again, the interesting fact that the locus of rupture surrounds the area of contact and is situated at a certain distance from it, may

be looked into. But if in the above formulæ the impressed surface is replaced by the area within the circle of rupture, the empiric law stated above is not changed. The source of discrepancy is not, therefore, to be found here.

(3) Nor does the assumption that the impressed surfaces may be relatively too large help us out of the dilemma. For in such a case the differences between theory and fact would vanish in proportion as $R/\rho$ is smaller. The results do not show this. In case of glass III, for instance, the ratios $P/D^2$ are still enormously different, for $\rho=4$ and $\rho=12$ $P/D^2=83.9$ and 56.4, respectively), whereas the quantity $R/\rho$ has already decreased to $\frac{1}{16}$ and $\frac{1}{23}$, respectively.

To decrease $R/\rho$ even beyond this, a new lens was made of the same glass with a radius as large as $\rho=30$ millimeters. In this case $R/\rho=\frac{1}{38}$ and $P/D^2$ ought therefore now either to coincide with the corresponding quantity for $\rho=12$, or at least to differ inappreciably from it. The data found for $P/D^2$, however (39.6 and 56.4), are very far from being constant, while $P/D2/3$ shows the same fixed values as above.

(4) I may instance, in passing, that in the case of different substances the quotients $P/D^2$ are independent of $\rho$. Thus, for the substances tested the values given dimensions of lens are: Glass I, 100; glass II, 105; glass III, 113; quartz, 135. Hence it is possible to obtain a *relative scale* of hardness which is not affected by the discrepancies here discussed, and therefore some certain progress has been reached, from a practical point of view at least.

(5) Summarizing the above, I am bound to confess that the cause of the discrepancy between theory and experiment has thus far eluded me. A gap must therefore be left in the theoretical side of the inquiry, with reference to which I would like to hazard the following suggestions: Compatibly with the relations which I have found experimentally, the last of the equations (4) leads to very different values of $P_1$ when different test lenses are employed. If therefore $P_1$ be termed the hardness of the material, the formula has no concrete meaning. Hence, either the stated definition of hardness must be rejected or one of the conditions, subject to which the equation was deduced, is not applicable. Saliently among these is the assumption that plate and lens are of the same material, and are therefore necessarily identical as to hardness. If this is not the case, then the hardness of one of the parts of the system is to be expressed in terms of the other (the equations for this computation are of an involved character), and with the aid of the observed data; or equation (4) can only yield a rough value for the mean hardness of the system of plate and lens at best. The point which I am approaching is this: Even if the lens and plate be cut from the same homogeneous solid it does not follow that they are necessarily equally hard, for hardness may reasonably be conceived to vary both with the substance and with the superficial curvature of the parts

at the point of examination. Clearly, in such a case, hardness would increase with the curvature at the point.

Evidence in favor of this surmise is already available, seeing that whenever the above experiments are carefully planned and executed, rupture always occurs in the plate, while the lens remains intact. Hence, in proportion as the lens is more convex it is also harder, and the value of the mean hardness of the system obtained from equation (4) must therefore increase with the lens curvature. This is what the experiments actually indicate. Pursuing this suggestion further, it follows that the equation expressing the hardness of the lens will be

$$H = a + \frac{b}{\rho},$$

where $a$ is the hardness of a plane surface of the given material (a constant which might be called *intrinsic hardness*), and $b$ the curvature constant, or, as it might be called, *surface hardness*. The close analogy between $b$ and the surface tension of liquids is obvious at a glance.[1]

As a second suggestion, I should like to propose a change of Hertz's definition of hardness. Hertz's characteristic contains three elements; it is (1) a pressure, (2) its direction, $Z_z$, is normal, and (3) it refers to the center of the impressed surface.

Since the criterion in case of brittle bodies is the occurrence of rupture, *i. e.*, a separation of parts, the immediate cause can not be pressure but tension. Furthermore, the crack passes from the surface $z = 0$, not quite normally perhaps, but nearly so, into the interior; and hence it is not $Z_z$ but an oblique pressure, indeed almost a lateral pressure, $X_x$, which is pre-eminently active. Finally since the crack encircles the area of contact, the component $X_x$ is here to be inserted. Unfortunately the complexity of the formulæ is such that a full solution of the problem can not be obtained for this case; they show however that $X_x$ reaches its maximum negative value on the outside of the surface of contact, and that the maximum is differently related to the lens curvature from the normal pressure. Obviously the latter is dependent on curvature in two dimensions, the other on the curvature in a single dimension. In short, even if the experiment leads to different values of $(Z_z)_{max}$ according as different lens curvatures apply, it does not follow that these different values may not all correspond to one and the same $(X_x)_{max}$. Perhaps these considerations may even be put more clearly by calling to mind that the maximum pressure on the surface produces no appreciable effect in this surface at all; its action, however,

An allied analogy is given by the tensile strength of iron wire, which, according to Baumeister (Wied. Ann., vol. 18, 1883, p. 578), is greater in proportion as the thickness of the wire is smaller. I have found that the law here is $F =$ const. $\sqrt[3]{d}$, or identical with the above relations. Some exceptions may reasonably be taken to all of these points.

is distributed radially until a line of rupture is the visible result. Hence it is not remarkable that constant results can only be reached if $P$ is divided by a low power of $D$.

### VIII. DATA FOR HARDNESS AND ELASTICITY.

The remarks of the preceding paragraph have shown that though the theoretical questions encountered in the present paper are in need of further elucidation, the considerations involved do not much affect the practical side of the issue. I have already pointed out that irrespective of the shortcomings of the theory, the relative scale of hardness is vouched for. Again there is one particular case in which the data are virtually absolute. This occurs when the curvature of the lens, $\rho=1$. Finally the absolute value of the data obtained will necessarily be general, since the facts show that by multiplying Hertz's expression by $\sqrt[3]{\rho}$, the results for a given substance are constant throughout. This datum may safely be taken as the absolute hardness of the body, although its mechanical interpretation is not quite apparent nor quite certain. Furthermore even these strictures will disappear, if the occurrence of a particularized surface hardness can be inferred from other and independent experiments, or if the dependence of tenacity and of hardness on lens curvature can be similarly computed in all cases. With these conditions premised the quantity $P_1\sqrt[3]{\rho}$ may be termed the absolute hardness of the body, and hence

$$H=\frac{6}{\pi}\sqrt[3]{P\,\rho\,q^2}$$

To give an example of the fluctuations here in question, the following two series of individual values of hardness may be adduced:

| | | | | | | |
|---|---|---|---|---|---|---|
| Glass I...... | H = | 220 | 230 | 222 | 218 | 227 ± 2. |
| $\rho=10$ ...... | | 234 | 236 | 222 | 231 | |
| Quartz...... | H = | 298 | 281 | 299 | ...... | 292 ± 2. |
| $\rho=1$ ...... | | 298 | 285 | 290 | ...... | |

It was my habit to compute all the values of $H$ individually. From these the following mean values of hardness were derived:

| $\rho=$ | 1 | 3 | 4 | 5 | 10 | 12 | 15 | 30 | Mean values. |
|---|---|---|---|---|---|---|---|---|---|
| Glass I ..... | 212 | ........ | 215 | ........ | ........ | 214 | ........ | ........ | 214 ± 1 |
| Glass II .... | ........ | 228 | ........ | 222 | 227 | ........ | 223 | ........ | 226 ± 2 |
| Glass III ... | ........ | ........ | 244 | ........ | ........ | 237 | ........ | 236 | 239 ± 2 |
| Quartz.... ⊥ to axis . | 292 | ........ | 298 | ........ | ........ | 293 | ........ | ........ | 295 ± 2 |

These data show a sequence of values which in the first place is qualitatively in accord with the usual scale of hardness (glass 4 to 6,

quartz 7). They further show a highly satisfactory degree of accordance (remembering always that this is the first attempt made to define hardness rigorously); for the errors lie within 1 per cent. In case of the individual values for glass even the extreme data lie far enough apart to indicate the difference of material. Nor is it remarkable that the value for quartz is not larger relatively to glass, seeing that all these bodies are closely related to each other. Indeed, I shall show elsewhere that quartz plates cut parallel to the axis are not harder than glass of average hardness.

Inasmuch as hardness thus appears as a particular kind of tenacity, it is interesting to compare the results obtained with tenacities obtained by other and more common methods. This can at once be done for glass, thanks to the elaborate reserches of v. Kowalski.* I will therefore compare his data for Thuringian glass with the mean of my values for hardness

*Tenacity of glass in* kg/mm²

| | |
|---|---|
| Tension | 8.8 |
| Flexure | 8.8 |
| Torsion | 10.1 |
| Compression | 37.7 |
| Hardness | 226. |

Hence longitudinal and flexural tenacity are about equally large, torsional tenacity is somewhat larger, compressional tenacity four times, and hardness twenty-six times as large as the first quantity.

I shall now attempt to avail myself of equation (5) and thus obtain the elastic constant $E^1$ and possibly the modulus $E^1$.

The following values obtain for $E^1$.

| Material. | Glass I. | Glass II. | Glass III. | Quartz. |
|---|---|---|---|---|
| $E^1$ | 5592 | 6960 | 7764 | 10 164 |
| Probable error | ±15 | ±24 | ±45 | ±18 |

Now $E^1$ contains both $E$ and $\mu$, and these can be individually measured only by a combination of methods; for instance, from data for flexure and torsion, or for longitudinal extension and radial contraction. In view of the peculiar signification of $E^1$, it is possible to obtain approximate results at least, without special experiments; for $\mu$ occurs in $E^1$ in the form of $(1-\mu^2)$, a function which does not markedly change even if the extreme values for $\mu$ be inserted.

According to Cornu,† Everett,‡ Voigt,§ Cantone,‖ and v. Kowalski ¶

* V. Kowalski: "Tenacity of glass." Wied. *Ann.*, 1889, vol. XXXVI, p. 307. The older results of Wertheim are much smaller.

† Cornu: *Compt. Rend.*, 1869, vol. LXIX, p. 333.

‡ Everett: *Phil. Trans.*, 1867, p. 139.

§ Voigt: Wied. *Ann.*, 1882, vol. XV, p. 497.

‖ Cantone: *Acc. Linc.*, 1888, vol. IV, pp. 220, 292.

¶ Kowalski, *l. c.*, p. 15.

the values of $\mu$ for glass lie between 0.208 and 0.264, and for these extremes the values of $(1-\mu^2)$ are 0.957 and 0.930, respectively. Furthermore, the mean value and probable error of $\mu$ will, in consideration of the weights of the individual measurements, be $\mu=0.225\pm0.008$, and therefore,

$$(1-\mu^2)=0.949\pm0.003.$$

Hence the error would be no larger than one-third per cent, but for the fact that $\mu$ is only given for very small strains. In case of marked deformation $\mu$, according to Röntgen* and others, is smaller; and when the body is incompressible (where $\mu=0.5$), the decrease in question is pronounced. These extreme conditions are without relevancy in the present case, and, proceeding from analogy, I shall put

$$(1-\mu^2)=0.97\pm0.01,$$

so that the probable error is 1 per cent. Hence to compute $E$ it is merely necessary to deduct 3 per cent from $E^1$, whence

| Material. | Glass, I. | Glass, II. | Glass, III. |
|---|---|---|---|
| $E=$ ....... | 5424 | 6751 | 7531 |

The elasticity of different glasses is therefore subject to large variations, and it is scarcely possible to make a detailed comparison with the results of other observers, as long as the character of the glass in question is not definitely specified. In how far my results are in keeping with such value may be gathered, in a general way, from the following interesting table:

| Substance. | Observer. | E. | Substance. | Observer. | E. |
|---|---|---|---|---|---|
| Soft glass............ | Auerbach......... | 5424 | Plate glass.......... | Wertheim ........ | 7015 |
| Crystal, containing Pb. | Wertheim[1] ....... | 5477 | Plate glass, Rhenish. | Voigt............. | 7358 |
| Greenish glass....... | Voigt[2] ............ | 6480 | Glass of Furth...... | Pscheidl.......... | 7427 |
| Thuringian glass .... | v. Kowalski[3]...... | 6702 | Belgian glass ....... | Pscheidl.......... | 7493 |
| Half hard glass...... | Auerbach......... | 6751 | Hard glass.......... | Auerbach......... | 7531 |
| Crystal .............. | Wertheim ........ | 6890 | Bohemian glass..... | Pscheidl.......... | 7550 |
| Plate glass........... | Pscheidl[4] ......... | 6920 | Window glass ...... | Wertheim ........ | 7917 |

[1] Wertheim and Chevandier: *Compt. Rend.*, 1845, vol. xx, p. 1637.
[2] Voigt: Wied. *Ann.*, 1882, vol. xv, p. 497.
[3] v. Kowalski: *l. c.*, p. 10.
[4] Pscheidl: Wiln. Ber., 1877, vol. lxxix, p. 114; 1882, vol. lxxxvi, p. 115.

It is my purpose to carry out a comparison of this kind systematically, by testing both the modulus of elasticity and the hardness of a great variety of glasses.

* Röntgen: Pogg. *Ann.*, 1876, vol. CLIX, p. 601.

For quartz the value $\mu$ has no immediate meaning, but the factor with which $E^1$ is to be multiplied to obtain the modulus $E_0$ in the direction of the axis is certainly nearer 1 than in the case of glass, seeing that both hardness and elasticity are more pronounced in the former case. Hence, the error made by putting $E_0=E^1$ or $E_0=10164$ will not be larger than 2 per cent. Indeed, this value when compared with Voigt's value, $E_0=10304$, agrees with it to about 1 per cent. In consideration of the totally different methods by which the two results are reached, the agreement is very satisfactory. Moreover, since the two data correspond to different intensities of strain, complete co-incidence is not to be looked for.

I will close with a short comparison of the values of hardness and elasticity. It appears at once that the harder of two bodies is the more elastic, but hardness increases less rapidly than elasticity. If $H$ be expressed in per cents of $E$, the following values obtain: Glass I, 3.9; glass II, 3.3; glass III, 3.2; quartz, 2.9. This state of things is strikingly manifest in the experiments themselves. One would naturally expect that greater pressures are to be brought to bear in the cases of the harder and more elastic bodies. As a rule the reverse of this is the fact. For in the case of the softer material the surface of contact rapidly increases, and hence greater pressures must be exerted to produce the same stress per unit of area.

# THE FLOW OF SOLIDS,*

## OR THE BEHAVIOR OF SOLIDS UNDER HIGH PRESSURE.

By William Hallock.

Among the many physical questions that are of vital interest to the student of structural geology the one which may well contend for a position in the front rank is, What is the effect of pressure, with or without a rise of temperature, upon the rocks and rock-making magmas which form the outer shells of our earth? As a very important subdivision of this general question we have this: What is the effect of pressures upon so-called solids *without* any rise in temperature above a point far removed from the ordinary melting point? In other words, can we liquefy solids by pressure alone? As corollaries we have any peculiarities at the instant of liquefaction and possible chemical reaction during this state of enforced liquidity.

These questions have long formed the subject of theoretical discussion, but in spite of the fundamental importance of their satisfactory and final settlement they have seldom been investigated experimentally, doubtless owing to the difficulty of obtaining, measuring, and managing sufficiently high pressures.

Walther Spring may perhaps be rightfully called the pioneer in this work, having within the last few years published the results of much experimental work upon this question. His memoirs † would seem to prove without doubt and finally, that pressures under 7,000 atmospheres will liquefy the large majority‡ of solids, and it is only a ques-

* From *Bulletin No. 55 of the U. S. Geological Survey.*

† *Bull de l'Acad. de Belg.*, 1880, 2d ser., vol. XLIX, and 1885, 3d ser., vol. IX; and *Bull. de la Soc. Chim. de Paris*, 1883, vol. XXXIX, and 1886, vol. XLVI.

‡ *Bull. de l'Acad. de Belg.*, 1880, 2d ser., vol. XLIX.

tion of a little higher pressure to accomplish the result even with the most refractory. Further than this, Mr. Spring has investigated the second corollary, and finds that chemical reaction takes place during this fusion;* at least when the volume of the products is less than that of the original substances.

Unfortunately however for the conclusive character of Mr. Spring's works, they have been seriously called into question, especially by Ch. Friedel.† Eduard Jannetaz‡ repeated many of Spring's experiments, and his results confirm Friedel's criticisms rather than Spring's conclusions, which he (Jannetaz) contradicts in every essential point.

Such was practically the condition of the question two years ago, when the Director of the U. S. Geological Survey, J. W. Powell, requested me to devote my time and thoughts to what we hoped would be its final settlement.§

It would be unjust to leave unmentioned here the elaborate and exhaustive series of experiments made by Henri Tresca‖ on "the Flow of Solids," which are fundamental as regards the point investigated, which however is but a small part of the general question.

In order that my meaning may be clear, I wish for myself and for this paper to impress certain meanings upon certain terms or words. Primarily, I wish strongly to distinguish between causing a body to "flow" and rendering it a true liquid. Any substance may "flow" when the force acting to cause the molecules to change their relative positions is greater than the force with which the molecules are held in their original positions; *i. e.*, is greater than the rigidity or viscosity of the substance. This can occur from two causes,—an increase of the force tending to disturb the molecules, or a diminution of the resisting power, the rigidity of the material. The first cause may take the form of pressure, strain, or such like force; the second cause is heat, and possibly other agencies. Whether rupture or flow takes place when the deforming overcomes the resisting force depends upon the nature of the substance, its limiting conditions, and *the time allowed for the accomplishment of the motion.*

It is impossible to draw a sharp line between "liquids" and "solids;" for convenience they may well be classed as true liquids, viscous liquids, viscous solids, true solids. In the first class would fall such substances as, in a small fraction of a second, fill their containing

* *Bull de l'Acad. de Belg.*, 1880, 2d ser., vol. XLIX, and 1885, 3d ser., vol. IX; and *Bull. de la Soc. Chim. de Paris*, 1883, vol. XXXIX, and 1886, vol. XLVI.

† Ch. Friedel, *Bull. de la Soc. Chim. de Paris*, 1883, vol. XXXIX, p. 626.

‡ Ed. Jannetaz, *Bull. de la Soc. Chim. de Paris*, 1884, vol. XL; *Bull. de la Soc. Minéral. de France*, 1885, vol. VIII, p. 168.

§ This paper is essentially taken from a report made to Maj. Powell, dated at Watertown, Mass., September, 1885.

‖ Henri Tresca, *Mém. de l'Inst. Savantes Étrangers*, 1868, vol. XVIII. *Comptes Rendus*, 1868, vol. LXVI; 1869, vol. LXVIII. See Tresca, in Bibliography, at end of article.

vessel to a horizontal surface. As true liquids we should then have such as alcohol, water, glycerine, molasses, etc. Viscous liquids require several seconds to fill their containing vessel to a level surface; thick tar is a good example. When the substance requires hours or even weeks in which to yield to gravity and change its form, I would call it a viscous solid; paraffin, shoemaker's-wax, and even lead and some other metals are such. A true solid retains its original shape indefinitely under ordinary conditions of pressure and temperature, as steel, glass, etc. Of course such a thing as an *absolutely* or *perfectly* rigid substance is as unknown to us as is an *absolute* or *perfect* fluid.

If the above ideas are correct, "true liquefaction" is the diminishing of the rigidity or viscosity of a substance until its molecules change their relative positions as easily as in a true liquid.

I give these definitions merely that I may be understood in the use of these terms, and not because I think them new or especially good. In order that a substance may undergo a change in its chemical or crystalline character, it is undoubtedly necessary that it should be in the condition, at least, of a viscous solid, so that the molecules can slowly re-arrange themselves, if there be any force urging them thereto. Our question is, Will pressure alone impart to the molecules such a freedom of motion? *A priori* it is inconceivable to me how or why it should. For with the exception of a few isolated substances at particular temperatures—as water between 4° C. and ice at zero—an increase of liquidity or a diminution of rigidity is simultaneous with an increase of volume—that is, with an increase of the inter-molecular distances, which is accomplished by "heating" the substance. *In general*, for one and the same substance over considerable ranges of condition, the rigidity diminishes as the inter-molecular distances increase. How then can pressing the molecules nearer together be expected to give them a property which always accompanies their separation?

## THE APPARATUS.

The first requisite for the experiments was pressure, and naturally desiring the best machine, we were able, through the kindness of Gen. Benét, Chief of Ordnance, to have the use in its spare moments of the testing machine built by A. H. Emery for that department, and situated at Watertown, Mass. This machine undoubtedly enables the operator to obtain—measure—and manage—high pressures better than any other.

Personally, I am greatly indebted to Capt. J. Pitman, of the Ordnance Corps, for suggestions as well on the construction of the holders as on the theoretical points; and also to Mr. J. E. Howard, the engineer in charge of the testing machine, for his knowledge of the capacity of materials, and their best shape and quality to obtain the results desired. The apparatus was constructed by the American Tool and Machine Company of Boston, Mass.

For the preliminary tests it seemed desirable to have a holder which could be opened, so as to show the compressed material in position, and finally the following form was adopted:

Diagram of apparatus used in work on high pressures.

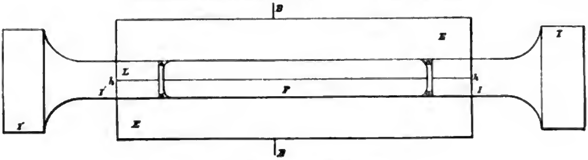

FIG. 1.—Longitudinal section.

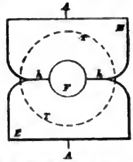

FIG. 2.—Transverse section.

Fig. 1 shows a longitudinal section on A A of Fig. 2. Fig. 2 shows a transverse section across the holder on the plane B B of Fig. 1. E E are the two halves in contact at *h h*, inclosing the cylindrical hole F, in which the substance to be pressed is placed. *h h* are strips of tissue paper, used as packing between two halves. I and I′, Fig. 1, are the two pins, acting as pistons, fitting into the hole F, to transmit the pressure; *a a* and *a a* are copper "gas-checks," placed in front of these pins, to flare out and fill tightly the hole, preventing any escape of material. Figs. 1 and 2 are about one-sixth of natural size. Fig. 3 shows the manner in which the apparatus was held in the testing machine and the pressure applied. P P P and P′ P′ P′ are the jaws of the hydraulic clamps of the machine (capacity 1,000,000 pounds). H H are merely blocks to enable the clamp to properly hold the holder E E. N is a block to hold the back stationary pin in place. The lettering in Figs. 1 and 2 apply in Fig. 3. V V is the hydraulic clamp on the fixed end of the testing machine where the pressure is weighed. The block B B moves on a spherical surface (R R) on the plate T T, thus permitting the adjustment of the face of O perpendicular to the line of pressure or parallel to the rear surface of the pin I. To apply the pressure, the movable clamp P P′ is forced toward V V by a hydraulic piston, thus forcing the holder E E over the pin resting against O; the pressure on O is measured by the hydraulic balance of the machine. In this manner a total compressive power of one million pounds was available, but as the pins yielded at 110,000 pounds per square inch, the tests were not carried above 6,409 atmospheres, or 96,000 pounds per square inch.

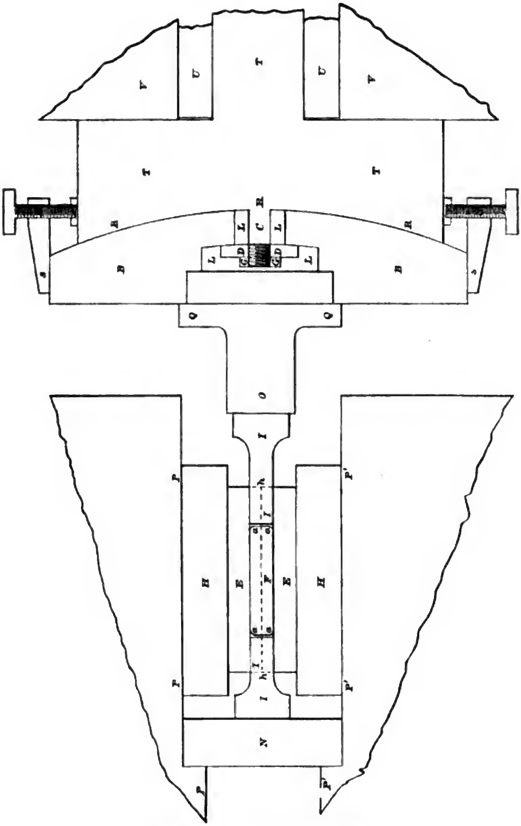

FIG. 3.—Part of testing machine.

## EXPERIMENTS.

With the above apparatus, used as described, the following tests were made:

### FIRST TEST.

A paper roll containing 1.557 pounds "c. p. granulated lead" was placed in the hole F, the gas-checks and pins were inserted, the holder halves clamped together, and the pressure was *slowly* applied; the amount of compression was measured in the distance to which E E had

been forced over the right-hand pin. Multiplying the simultaneous loads and compressions, we obtain the *work* done, and hence the possible heat generated. In this experiment the work done was 2,330 foot-pounds, or 3.0 thermal units, 1 pound 1° F., sufficient to raise 1.557 pounds lead *alone* about 63° F., or 34° C. If the heat generated is dissipated into the holder E E, as is sure to be the case, the rise in temperature would be less than 1° C., or 1°.8 F.

Under a pressure of 6,000 atmospheres the granular lead showed not the least sign of true liquefaction. It was merely pressed together, and could easily be broken up and reduced to the original grains between the thumb and finger. It is true these experiments were not performed *in vacuo*, a condition which Walther Spring considers of importance. But if there is a true liquefaction, why does not the air rise to the top of the cavity and allow fusion, as it does when the granular lead is heated? There is no liquefaction, only a pressing and sticking together.

SECOND TEST.

Next 0.672 pounds* of antimony was ground in a mortar until it went through a 48-sieve, and then it was similarly submitted to 6,000 atmospheres pressure, with the same result; the grains were simply stuck together, and were perfectly distinct in their original form. The cylinder formed was hard and tenacious, but gave no signs of liquefaction or recrystallization. The work done in this case might have raised the antimony alone 230° F., or 110° C., or holder and antimony 1°.8 F., or 1° C.

THIRD TEST.

Well-crystallized calcite, 0.271 pounds† was ground, put through a 48-sieve, and submitted to a pressure of 6,000 atmospheres, producing practically no effect, the resulting mass being easily broken between the thumb and finger.

Finding it useless to have large quantities of the compressed material for elaborate examination, it was decided to expedite matters by putting in several substances at one time, and the following rather crucial test was made:

FOURTH TEST.

L H, left-hand pin, stationary. R H, right-hand pin, entering the hole F, moving.

The charge was composed as follows:

A. Small section of antimony from test II.
B. A stick of beeswax, whittled round, nearly fitting the hole.
C. A stick of paraffin, whittled round, nearly fitting the hole.
D. Bismuth prepared like the antimony for test II.
E. Paraffin, same as C.
F. Lead from test I.

* 0.672 pounds antimony, solid, filled the hole F, 5 inches long.
† 0.271 pounds of solid calcite fills the holder, 5 inches in length.

*d d* were double-pointed tacks stuck into the top of the beeswax and paraffin, and at *a* and *c* two old *silver* 3-cent pieces were laid on top of the wax and the paraffin in the cylinder.

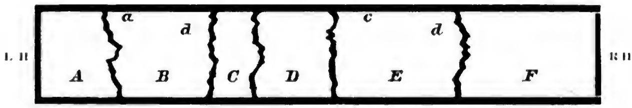


FIG. 4.—Diagram showing experiment.

What are we to expect? The silver pieces and tacks would fall through the liquid wax and paraffin, and B and C, if liquid, would mix. Nay, according to Spring's results, we should expect to find along the lower part of the mold a semicylindrical piece of an alloy of lead, antimony, bismuth, possibly silver and iron, and above this the mixture of paraffin and wax. The actual result was that the substances *all came out just as they went into the press.* There was not the slightest trace of a tendency to flow on the part of the metals; the lead and antimony remained as they were, the bismuth acted precisely as did the antimony in test II. There was no sign of fusion of the wax and paraffin, which separated on their surface of contact (between B and C) clear and distinct. *a*, *c*, *d*, and *d* did not sink to the bottom—on the contrary, they retained their original positions; and the silver pieces were forced against the *top* of the cylinder so powerfully that their impression left in the steel holder was easily seen and *felt*, and the pieces were bent cylindrical, fitting the inside of the holder. Here we find a much greater rigidity of wax and paraffin under pressure than ordinarily supposed possible under any circumstances.

Nowhere was there a sign of true liquefaction. The wax and paraffin had acted only as viscous solids, and flowed only to fill the available opening.

FIFTH TEST.

In a similar way the following substances were subjected to a pressure of 6,000 atmospheres, with the results as stated:

Sodium carbonate, dry.—Stuck together slightly, resembling chalk; easily cut with a knife.

Sodium sulphate.—Probably dissolved in its water of crystallization ($10H_2O$): it was forced out between the halves of the holder as a milky liquid which solidified. The little left in the holder resembled paraffin in appearance, but soon weathered to a white powder.

Zinc sulphate ($+7H_2O$).—No signs of fusion; merely stuck together; the original pieces of crystals easily visible.

Copper sulphate ($+5H_2O$).—Same as zinc sulphate.

SIXTH TEST.

Potassium chloride.—Formed a hard lump, whose fracture resembled that of loaf sugar or that of marble, with the original crystals visible; no trace of fusion.

Sodium chloride.—Similar to potassium chloride, only a little more compact.

Ammonium chloride.—Still more compact, resembles vegetable ivory; possibly the beginning of fusion. Observe the order of increasing effect:

$$KCl < NaCl < NH_4Cl.$$

Sulphur roll.—Ground and put through a 48-sieve; formed a hard, solid, brittle mass, but the original grains were easily distinguishable, there being no trace of a true liquefaction.

SEVENTH TEST.

Powdered glass.—No effect; scarcely coherent.

Powdered rosin.—Very good fusion.

Powdered borax.—A compact, chalk-like mass, *slightly* translucent; no crystallization.

Powdered zinc and sulphur.—No trace of fusion or chemical union apparent. Carbon disulphide dissolved out the sulphur so completely that the remaining zinc gave a mere trace of sulphureted hydrogen on treating with hydrochloric acid. The zinc was slightly coherent, but there was no fusion and no zinc sulphide formed.

After obtaining the above results it seemed useless to continue this line of experiments, and preparations were made to use more rigid steel, by which it was hoped that pressures of at least 10,000 atmospheres might be obtained; also for making the compressions *in vacuo*. Unfortunately thus far nothing but preparations have been made, since the testing machine is kept fully occupied with the special work of the department to which it belongs. It is hoped, however, that this investigation will soon be taken up again and carried to a close; till then our conclusions are only temporary.

The above substances were also compressed by W. Spring* *in vacuo* with the following results:

Lead.—Perfect fusion at a pressure of 2,000 atmospheres. At a pressure of 5,000 atmospheres it ran out of all the cracks (*fentes*) of the apparatus.

Bismuth.—At a pressure of 6,000 atmospheres, perfect fusion.

Tin.—At a pressure of 3,000 atmospheres, fusion.

Zinc.—At a pressure of 5,000 atmospheres, perfect fusion.

Antimony.—At a pressure of 5,000 atmospheres, beginning of fusion.

Sulphur, prismatic.—At a pressure of 5,000 atmospheres, fusion to the octahedral form.

Sulphur, plastic.—At a pressure of 6,000 atmospheres, fusion to the octahedral form.

Sulphur, octahedral.—At a pressure of 3,000 atmospheres, fusion to the octahedral form.

Potassium chloride.—At a pressure of 5,000 atmospheres, perfect fusion.

Sodium chloride.—At a pressure of 5,000 atmospheres, perfect fusion.

Ammonium chloride.—At a pressure of 4,000 atmospheres, perfect fusion.

Sodium sulphate ($10H_2O$).—At a pressure of 3,000 atmospheres, perfect fusion.

Zinc sulphate ($7H_2O$).—At a pressure of 5,000 atmospheres, perfect fusion.

Copper sulphate ($5H_2O$).—At a pressure of 6,000 atmospheres, completely crystallized.

Sodium carbonate, dry.—At a pressure of 5,500 atmospheres, stuck together (*aggloméré*.)

Iceland spar.—At a pressure of 6,000 atmospheres, imperfect fusion.

Borax (crystallized).—At a pressure of 7,000 atmospheres, imperfect fusion.

Glass (powdered.)—At a pressure of 6,000 atmospheres, no effect.

And so on to the end.

* *Bull. de l'Acad. Roy. de Belg.*, 1880, 2d ser., XLIX. p. 326.

Excepting the last four substances mentioned, our results are directly opposed to those of Spring, but support the criticisms of Friedel and Jannetaz.

## CONCLUSIONS.

Conclusions at this stage of the investigation are necessarily premature and tentative; still it may not be out of place to summarize the results of these and other experiments.

It seems established that pressure alone can not truly liquefy a solid, *i. e.*, diminish its rigidity. Consequently, we can scarcely expect chemical and crystalline changes by pressure alone. Solids can be made to flow and act in that respect, as liquids, by pressure, which overcomes the rigidity without diminishing it. In this case the time allowed for the motion is of vital importance.

Whether further investigation will alter these conclusions or not is a question of time; at present, I believe them the only true ones to be drawn from the available facts.

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An abstract of the foregoing article appeared in the *American Journal of Science*, 1887, vol. XXXIV, 3d series, p. 277. In a note published in the same journal (1888, vol. XXXV, p. 78), Mr. Spring violently attacks my interpretation of our results, especially my use of the word "fusion," which I have employed in its secondary sense, as meaning *a uniting as if by melting with heat;* the case of actual fusion by heat being specifically excluded. It seemed to me best to leave the word in the above article and make this explanation of its use. See, also, W. Spring, *Bull. Acad. Roy. Belg.*, 1888, vol. XVI, p. 43; also *Am. Jour. Sci.*, 1888, vol. XXXVI, p. 286. And W. Hallock, *Am. Jour. Sci.*, 1888, XXXVI, p. 59; also *ibid.*, 1889, vol. XXXVII, p. 402; also *Zeitschr. für Phys. Chem.*, 1888, vol. II, p. 378.

# THE SCIENTIFIC WORK OF GEORGE SIMON OHM.*

By Eugene Lommel.

Translated by William Hallock.

One hundred years ago, on the 16th of March, 1789, George Simon Ohm was born at Erlangen. His father was a lock-smith, an unusual man, who trained both his sons in mathematics as well as his trade. These gifted young men were endowed by him with that thirst for knowledge which led him to devote his riper years to mathematical studies. The younger brother, Martin Ohm, became distinguished as a mathematician, and died as professor of mathematics at the military school at Berlin. George Simon Ohm climbed to the lofty position of those rare men whose names shine with everlasting glory in the history of science, which they have enriched with their wonderful discoveries.

Only a few of his contemporaries could fully appreciate the unpretentious scientist, or estimate the wide application of his law of the galvanic current, with the discovery of which his scientific career commenced. In the beginning of the century Volta had discovered his "pile," that most marvellous structure that the keenness of the human mind ever devised. From that moment numerous physicists had been ceaselessly active, investigating in every way the wonderful and manifold effects of the electric current which that pile produced.

The decomposition of water had been discovered in 1800 by Nicholson and Carlisle. Twenty years later the deflection of the magnetic needle was observed by Oersted. Thermo-electricity was discovered in 1821 by Seebeck; electro-dynamic phenomena, in 1823, by Ampére. In 1821 Schweigger and Poggendorff invented the galvaniscope ("multiplicator"), which first rendered possible the accurate measurement of the effects of the current. The multitude of observations became more numerous in proportion as more varied means of investigation became available. Nevertheless they were not able to lift the mysterious veil which shrouded the workings of the galvanic current. On the contrary, they seemed rather to increase the Babel of conflicting theories.

We are filled with strange sensations, glancing to-day through the articles of that time upon the galvanic current. We see the most experienced investigators doubtfully groping in darkness where to-day,

*An address delivered at the public meeting of the Royal Bavarian Academy of Sciences of Munich, March 28, 1889.

thanks to Ohm's discovery, all is to us clear and evident. The majority of the galvanists of the day indeed seemed contented in the labyrinth in which they had involved themselves. They did not seize the thread of Ariadne which the sharp-sighted investigator seized at last. These pioneer services of Ohm at first remained generally unappreciated. Only individual physicists, like Poggendorff and Schweigger, Pfaff and Fechner, recognized their great importance, and with success in their work used this new enunciation. It required a foreign impulse to win recognition in Germany for his law of the intensity of the current. This law is always meant when "Ohm's law" is referred to. Pouillet established Ohm's law in France by the articles which he published in 1831 and 1837, five and eleven years, respectively, after Ohm's discovery. In spite of this fact Pouillet believed himself the real discoverer, because he had found it experimentally. Pouillet believed that Ohm had only deduced it mathematically from certain hypothetical premises. In France the belief arose that Ohm found his law by simple deduction based upon an hypothesis, and then subsequently verified it by experiment. This belief remains to the present day in spite of frequent contradictions. It is found to-day not only in French treatises, but, most inconceivably, even in widely used German text-books. It would thus appear by no means superfluous to set forth the history of Ohm's great discovery, in its actual course and based upon original publications.

Experimental investigation strives to recognize a law of nature by attempting to establish the dependence of the effect in any natural phenomenon upon its determining cause. Measurements are made in as many individual cases as possible. Then some relation is sought, in the shape of an equation, which shall express this dependence and re-produce all the individual cases as accurately as possible. In the choice of this equation mistakes will occur which can not be immediately detected. The one taken may sufficiently conform to the available observations, which may embrace too small a range of the determining quantity, and may fail utterly when this range is extended. Then it can not be looked upon as the expression of the law of nature sought, which must cover all cases without exception.

Ohm followed this experimental method when, in 1825, he tried to establish the law of conduction. He was at that time a teacher in the public school (gymnasium) at Cologne. The experiments made for the above purpose were described in an article entitled "Preliminary notice of the law according to which metals conduct contact electricity," Schweigger's *Journal*, 1825, vol. XLIV. His "preliminary notice" was too hasty. The formula which he proposed is incorrect. It is:

$$v = m \log \left(1 + \frac{x}{a}\right)$$

wherein $m$ and $a$ are constants, and $v$ the loss of force on introducing a length of wire equal to $x$. Ohm soon recognized the cause of this

failure in the too limited range of his experiments and in the fluctuations in the force of the galvanic battery. Much later the invention of the constant cell obviated these fluctuations.

In the summer of the same year, 1825, and in the same volume of Schweigger's *Journal*, appears a letter from Ohm to the editor. He says in consequence of more extended experiments he is moved to replace his formula with a new but analogous one. In this the force would only vanish for $x = \infty$.

Not long after this, in the spring of 1826, vol. XLIV of Schweigger's *Journal* contained that wonderful pioneer work which contains the experimental discovery of the law of the intensity of the current. Its title is: "Determination of the law according to which metals conduct contact electricity, together with the outlines of a theory of Volta's apparatus and the Schweigger's galvanoscope." In the introduction to this article Ohm expresses the hope that he is in a position to propose what will appear to be a true law of nature. First, on account of its perfect agreement with experiments extended in all directions; second, and especially because of its simplicity which extends it to all our experience with the electric current. A simplicity such as is only found in truth.

The "fluctuations of force" had disturbed Ohm greatly in his former experiments, Poggendorff suggested that he should use a thermo-electric instead of a hydro-electric battery. This he did and now the law appeared in perfect distinctness from his measurements. *The intensity of the current is directly proportional to the exciting force and inversely proportional to the total resistance.* This he represented in the equation

$$X = \frac{a}{b+x}$$

"wherein X is the intensity of the magnetic effect of the conductor whose length is $x$, $a$ and $b$ represent constant quantities depending upon the exciting force, and the resistance to conductivity of the other parts of the circuit.

In this law he held in his hand the key to the various riddles before which physicists had hitherto stood helpless. And indeed he knew how to use that key! Farther on he says: "Our equation has now sufficiently established itself as the accepted representative of nature by the correctness with which it always repeats the results obtained in such profusion from the thermo-electric battery. Let us follow it farther and see what it may still hold concealed in its lap."

Ohm then developed the peculiarities of the galvanic battery and galvaniscope, which till then had appeared so confused and unintellible. And we in our text-books to-day follow his development. Bubbling over with joy in the feeling that he had beheld the face of truth. he may well feel a justifiable pride. At the close of that wonderful work he exclaims: "The theories of the battery and galvaniscope, here

sketched in rough outline, are established even better by the truth of the law of the conduction of the current in metals here set forth, than they are by the experiments themselves from which they were derived. Effects of the galvanic current apparently the most varied are reduced to a striking simplicity."

What Ohm here and in the title calls "theory" is limited to the immediate consequences of his law determined inductively. It has nothing in method in common with the truly so-called "theory" which he proposed much later in his famous work, "The Galvanic Battery," and which he evolved deductively upon premises and partly hypothetical considerations.

It is hence perfectly clear that Ohm discovered his law in the purely empirical way. Six years later, October, 1831, Pouillet appeared in an article on the application of the thermal battery to the determination of the law of intensities in a constant current. What Pouillet believed himself the first to do, had already been done by Ohm in the above article in the most complete manner. Nowhere in his article is there so much as a suggestion of a hypothetical consideration which might have influenced him in the choice of his mathematical expression. The fact above stated that the formula first proposed was wrong, affords the most striking proof that those theoretical considerations which enabled him later to deduce his law mathematically, were at that time quite remote.

Ohm's name has been made immortal by this typical experimental treatise. It contains the discovery of the law of the intensity of the current, fully and completely, along with the most important conclusions to be deduced therefrom. In view of this inherent value it is undoubtedly to be preferred to the other most important works of Ohm, even to that one most famous of all his writings, "The Galvanic Battery Treated Mathematically," which has always held the highest place in public estimation. In that experimental investigation he robbed nature of her secret and announced that everlasting and immutable law of nature which will outlive all the variations of theoretical beliefs.

A mind like that of Ohm, trained and accustomed mathematically to inquire into the causes of phenomena, must soon have felt the need of showing that what he had inductively recognized was deductively a necessary consequent of simple conceptions as to the way in which electricity appears at the point of contact of different substances and disseminates itself in conducting materials.

In the same year 1826 he published an article entitled: "Attempt at a theory of the electroscopic phenomena produced by galvanic forces." He reports the happy result of his endeavors in that he not only re-discovered, in this opposite way, the experimentally determined law of the intensities of current, but also found a second, no less important, the electroscopic law or law of tensions.

This communication was but the precursor of that classic work so frequently referred to: "The Galvanic Battery Treated Mathematically." This he produced in the quiet of a much-needed vacation, and published in May, 1827.

In the introduction to this article he says his aim has been "to deduce in connected sequence and from a few principles those electrical phenomena which are comprehended under the epithet galvanic; the purpose is accomplished if the variety of facts is subordinated to the simplicity of comprehension." Indeed he accomplished his purpose most completely. He extended to electrical conduction the ideas of Laplace, Poisson, and especially Fourier on the conduction of heat, and evolved the laws of the electric current with the mathematical means which those investigators had created for their own purposes. This thoughtful theory of Ohm stands to-day unshaken,—a compactly constructed whole. In order to bring it into unison with the present views concerning electricity it is only necessary to remark that what Ohm calls "electroscopic force" or "tension" is nothing but electrical potential.

The Laplace-Poisson equation, which formed the basis of Ohm's deductions, shows indeed that in a conductor carrying constant electric currents, as well as in one in electric equilibrium, the free electricity is all distributed on the surface. The surface layer, however, in the case of the currents shows a different distribution from that in the condition of equilibrium. Ohm, on the contrary, assumed that the free electricity was spread over the whole cross-section of the conductor carrying the current. This assumption called forth many contradictions, because it was so foreign to the nature of electricity. By removing this contradiction newer views, without changing in the least Ohm's formula or conclusions, have only served to establish the theory all the more firmly. The subsequent extension of his theory, by its application to conductors of two and three dimensions, was an immediate generalization of his method of treatment which Ohm himself foresaw; also, the enunciation in that well digested work of Ohm's on the non-constant or charging and discharging currents, stands to-day in unchanged correctness.

As has already been emphasized, the first discovery of Ohm's law as to the intensity of current is not contained in that master investigation. The law previously discovered and proven by experiment served only as the touchstone for the theory of which it appeared to be a necessary consequent. But the brilliancy of this theoretical accomplishment threw his previous tedious work of empirical investigation so into the shade that it is partly conceivable how the belief arose that Ohm mathematically deduced his law from debatable hypotheses.

At first Ohm received no recognition from even this work. It received no attention in many circles; from many sides came sharp criticism; from only a few genuine approval. His hopes of being able

to follow an academic career were dashed by hard disappointment and he resigned his position as teacher at the gymnasium and retired, discouraged, to private life. The cramped position in which he now saw himself placed must have been depressing for his spirits. Still this period of six years which elapsed until his appointment as professor of physics in the polytechnic school, at Nuremberg, in 1833, was not entirely barren for science. In a series of articles, published mostly in Schweigger's *Journal*, he furnished renewed experimental proof of the law discovered by him. We find in these teeming articles the law of the branching of currents (Schweigger's *Journal*, 1827, vol. XLIX); observations on the "fluctuations of force," on the poalariztion of electrodes and transition resistance, beside methods for determining galvanic resistance and electromotive force. An article from this period is especially worthy of notice as a model of experimental investigation, entitled "experiments on the more accurate comprehension of uni-polar conductors." In it he entirely explained, by a complete series of well-chosen experiments, the enigmatical phenomena of so-called uni-polar conduction.

The above-mentioned article of Pouillet, in 1837, and the claim made in connection with it, finally brought Ohm's discovery to the attention of physicists at home and abroad. Especially in England was its far-reaching importance immediately recognized. The Royal Society, at its annual meeting of November 30, 1841, conferred upon the unassuming German scientist the gold medal which Copley had established as a prize for the most conspicuous discovery in the domain of exact investigation. The medal was accompanied by a formal letter of presentation, which points out in strong terms Ohm's services to galvanism, and which is no less an honor to the learned society than to the recipient of the prize. Thus Ohm received abroad the tardy recognition which his native land had so long withheld. He gave touching expression to his gratitude in the dedication of his work "Contributions to Molecular Physics" to the Royal Society of London, which by its words of approval had given his courage new strength for continued strife in the field of science, weakened as it was by previous discouraging experiences.

His creative genius, which seemed to lie fallow during the last years, awoke anew. Soon he was successful in a second great venture, this time in the field of acoustics, (upon which he had entered in 1839,) in a "Note on Combination Tones." In his article "On the Definition of Tone and a Consequent Theory of the Siren and Similar Tone-Producing Apparatus," he established, in 1843, the law of acoustics also known by his name. Inasmuch as this law furnishes the clearest insight into the hitherto incomprehensible nature of musical tones, it dominates the acoustics of to-day no less completely than does his law of the electric current dominate the science of electricity. This law states

that the human ear perceives only pendulum-like vibration as a simple tone. Every other periodic motion it resolves into a collection of pendulum-like vibrations which it then hears in the sound as a series of single tones, fundamental and overtones. Ohm arrived at this law from mathematical considerations, making use of Fourier's series; for its experimental verification he was compelled to use the well-cultivated ear of a friend, inasmuch as he was himself entirely devoid of musical ear.

Like his law of the current, this law of acoustics received no recognition from his contemporaries. It was, in fact, opposed by Seebeck, one of the most prominent investigators in that field, as being an idea too foreign to the accustomed method of presentation. This law of Ohm was not accepted until Helmholtz furnished the experimental means which enables every even unskilled ear to resolve a sound into its simple partial tones; and eight years after Ohm's death completely revolutionized acoustics and the theory of music by that classic work, "The Science of the Perception of Sound," which is based on Ohm's law.

In 1827, while Ohm was writing the appendix to his work, "The Galvanic Battery," certain ideas in regard to the ultimate structure of matter were forced upon him. "There are properties of space filling matter which we are accustomed to look upon as belonging to it. There are other properties which heretofore we were inclined to look upon as the visitors of matter which abide with it from time to time. For these properties man has thought out causes if not foreign, at least not innate, and they pass as immaterial and yet independent things of nature, under the names of light, heat, electricity, etc. It must be possible to so conceive the structure of physical bodies that along with the properties of the first class, at the same time and necessarily those of the second shall be given." This thought appears to have been suggested by his broadly designed plan of "Contributions to Molecular Physics." The recognition of the Royal Society gave him new courage for the carrying out of this work, but unfortunately it remains unfinished. His intention appears to have been, from certain definite assumptions concerning the nature, form, size, and mode of action of the atom, to deduce, by the aid of analytical mechanics, all the phenomena above referred to. He desired to create a work that should be for the microcosm of the world of atoms, what Newton's "Principia" had become for the microcosm of heavenly space. Only the first volume appeared. It was entitled "Elements of Analytical Geometry of Space on a System of Oblique Co-ordinates," and contained only the mathematical introductin to the actual problem. A second volume was to have contained "the dynamics of the structures of bodies," and a third and fourth to be devoted to the physical investigation itself.

Toward the end of 1849, in the midst of eager work upon his great

task, he was called to Munich as curator of the mathematical and physical collection of the Royal Academy of Sciences. He was also to be adviser of the ministerial director of telegraphs, and was obliged to lecture on mathematics and physics as professor at the university. Thus for the man of sixty the desire of his youth was tardily fulfilled, too tardily and hence scarcely to the benefit of science. The manifold duties of his new sphere of activity prevented the completion of his great work, and robbed posterity of the legacy which Ohm had intended to leave it from the rich treasures of his thoughts. However, it is by no means true that this period at Munich was entirely without gain for science. Optics had always been a pet object of his activity. In 1840 in Poggendorff's *Annalen*, vol. XLIX, he published a "Description of some simple and easily managed arrangements for making the experiment of the interference of light." In it he showed how French interference prisms which worked very well could be made from common plate glass; indeed, how a simple strip from the edge of a piece of plate glass could be used for the purpose. In 1852 and 1853 in his great work, "Explanation of all perceivable interference phenomena of plates of miaxial crystals in plane-polarized light," he set himself the task of developing in a most general way than had been done, the theory of these phenomena so rich in form and color. He arrived at a formula of great simplicity and beauty, and which covered all the individual colors. This work has many points in common with one by Prof. Sangberg of Christiania, published complete in Norwegian in 1841, in the "Magazin for Naturvidenskaberne" (natural sciences), and abstracted in 1842 in the first extra volume (*Ergänzungsband*) of Poggendorff's *Annalen*. The title of Sangberg's work was, "Analysis of the isochromatic curves and the interference phenomena in combined miaxial crystals." Ohm first learned of this work after the completion of his own, which was, however, by no means rendered superfluous by Sangberg's. The phenomena of elliptical interference rings which had led Ohm to his investigation, had also been observed at the same time by Sangberg.

Among the causes which prevented Ohm from continuing and completing his molecular physics was the writing of a text-book of physics for his students. In spite of the "aversion always felt to working out a text-book," he still felt impelled to the work by having accepted the position of instructor. He accomplished the speedy completion of this thoroughly original work by lithographing his lectures as fast as they were delivered and giving copies to his classes. The strain caused by so quick an accomplishment of so difficult a task had a bad effect upon his health, as he sadly acknowledges at the close of the preface of his text-book (Easter, 1854). One other expression in the text of the book dimly suggests his feeling that his strength was expended. As a result of repeated attacks of epilepsy, on July 6, 1854, he yielded up that life which to its last breath was devoted to the search after truth.

We have thus far striven to set forth in hasty outline what Ohm has been to science, without mentioning more of the other circumstances of his life than were necessary to an understanding of his scientific services. This has seemed permissible because, on the one hand, Lamont in 1855 delivered from this place an address which also covered the biographical points of his career. On the other hand, another member of our academy, Privy Councilor von Bauernfeind, a pupil and friend of the one immortalized, in his "Memorial address on Ohm, the physicist," has given us a complete presentation of the life of his teacher, drawn from reliable sources and from personal acquaintance.

The deeds of a scientist are his scientific investigations. Truth once discovered does not remain shut up in the study or the laboratory. When the moment comes it bursts its narrow bonds and joins the quick pulse of life. That which has been discovered in solitude, in the unselfish struggle for knowledge, in pure love of science, is often fated to be the mighty lever to advance the culture of our race. When nearly a hundred years ago Galvani saw the frog's leg twitch under the influence of two metals touching, who could have suspected that the force of nature which caused those twitchings would transfer the thoughts of man to far distant lands, with lightning's speed, under the the waters of the ocean—would even render audible at a distance the sound of the spoken word! That this force of nature—after man by ceaseless investigation had learned to vastly increase its strength—would illuminate our nights like the sun! This enormous development of electro-technology, which we have followed with amazement in the last decades, could only be accomplished upon the firm foundation of Ohm's law. For only he can govern a force of nature who has mastered its law. Ohm by wresting from nature her long-concealed secret has placed the scepter of this dominion in the hand of the present.

This great service of Ohm and the fundamental importance of his law, as well for the science as for the technology of electricity, are to-day generally recognized. In order permanently to honor his memory, the international congress of electricians, assembled at Paris in 1881, determined to call "an ohm" the unit of resistance to conduction, then fixed and now generally accepted, after the name of him who introduced this important conception into the science and technology of electricity. Thus it happens that the name of the modest scientist who never strove for show or glory is to-day upon the lips of the thousands who are busy in our highly developed electro-technical industries.

Although this ideal monument is the most beautiful and the most lasting, yet the duty of gratitude seems to urge that posterity, which has gathered the rich fruit of his industry as an investigator, should also honor the memory of the great physicist with a visible monument.

This idea was suggested by the hundredth anniversary of Ohm's birth, which we are to-day tardily celebrating. In order to carry it

out, a committee was formed for the erection of an Ohm statue in Munich, the capital of his more particular fatherland, where in the evening of his life, after long waiting, he found a sphere of activity worthy of himself.

Our suggestion found lively approval and active furtherance not only within the boundaries of the German Empire, but far out beyond. Thus we may hope at no distant time there will arise in our capital a worthy monument, a visible witness of the glory of our great countryman, a witness also of the spontaneous gratitude of the nations.

# JohannJUSTUS VON LIEBIG.

## AN AUTOBIOGRAPHICAL SKETCH.*

Translated from the German, by Prof. J. CAMPBELL BROWN.†

My father, who had a color ware-house, frequently occupied himself in making some of the colors in which he dealt, and for that purpose had fitted up for himself a small laboratory to which I had access, and where I sometimes enjoyed the privilege of helping him. He made his experiments as prescribed in works upon chemistry, which were, with great liberality, lent to the inhabitants of Darmstadt from the rich court library.

The lively interest which I took in my father's labors naturally led me to read the books which guided him in his experiments, and such a passion for these books was gradually developed in me that I became indifferent to every other thing that ordinarily attracts children. Since

*Read at a joint meeting of societies in the chemical laboratories, University College, Liverpool, on Wednesday evening, March 18, 1891, by Prof. J. Campbell Brown, D. Sc. (From *The Chemical News*, June 5 and 12, 1891; vol. LXIII, pp. 265–267 and 276–278.)

† [At the recent celebration of the jubilee of the Chemical Society, reference was made to the wonderful energy and ability of Liebig; to the great work which he did in founding organic chemistry, and to the immense stimulus which he gave, alike in his own country and in England, to scientific investigation in pure chemistry and in its applications to agriculture, physiology, and pathology.

Very opportunely a portion of an autobiographical sketch in Liebig's own handwriting has just come to light, in which he gives a most interesting account of the formation of his habits of thought, and of the development of his scientific activity. He also gives an amusing description of the lectures given in his student days by professors of the deductive method.

In his sixtieth year, we are told, Liebig wrote some biographical sketches which were laid aside and could not be found when he wished to resume them. They were never finished. A portion of the manuscript was found among some other papers in Liebig's handwriting, by his son, Dr. Georg Baron von Liebig, and has been published by the latter in the *Deutsche Rundschau* for January, 1891. Mr. E. K. Muspratt has been good enough to lend me a copy which he received from his friend, the present baron.

I have endeavored to render it into English as literally as the difference in the idiom and modes of expression in the two languages will permit; and it is now made public in England by the kind permission of the *Deutsche Rundschau*.

His method of teaching and its remarkable success are worthy of attention at the present time, when technical education is occupying so much of the public mind.]

I did not fail to fetch the books from the court library myself, I became acquainted with the librarian, Hess, who occupied himself successfully with botany, and as he took a fancy to the little fellow, I got, through him, all the books I could desire for my own use. Of course the reading of books went on without any system. I read the books just as they stood upon the shelves, whether from below upwards or from right to left was all the same to me; my 14-year-old head was like an ostrich stomach for their contents, and amongst them I found side by side upon the shelves the thirty-two volumes of Macquer's "Chemical Dictionary," Basil Valentine's "Triumphal Car of Antimony," Stahl's "Phlogistic Chemistry," thousands of essays and treatises in Göttling's and Gehlen's periodicals, the works of Kirwan, Cavendish, etc.

I am quite sure that this manner of reading was of no particular use so far as acquisition of exact knowledge is concerned, but it developed in me the faculty, which is peculiar to chemists more than to other natural philosophers, of thinking in terms of phenomena; it is not very easy to give a clear idea of phenomena to anyone who can not recall in his imagination a mental picture of what he sees and hears,—like the poet and artist, for example. Most closely akin is the peculiar power of the musician, who while composing thinks in tones which are as much connected by laws as the logically arranged conceptions in a conclusion or series of conclusions. There is in the chemist a form of thought by which all ideas become visible to the mind as the strains of an imagined piece of music. This form of thought is developed in Faraday in the highest degree, whence it arises that to one who is not acquainted with this method of thinking, his scientific works seem barren and dry, and merely a series of researches strung together, while his oral discourse when he teaches or explains is intellectual, elegant, and of wonderful clearness.

The faculty of thinking in phenomena can only be cultivated if the mind is constantly trained, and this was effected in my case by my endeavoring to perform, so far as my means would allow me, all the experiments whose description I read in the books. These means were very limited, and hence it arose that, in order to satisfy my inclination, I repeated such experiments as I was able to make, a countless number of times, until I ceased to see anything new in the process, or till I knew thoroughly every aspect of the phenomenon which presented itself. The natural consequence of this was the development of a memory of the sense, that is to say of the sight, a clear perception of the resemblances or differences of things or of phenomena, which afterwards stood me in good stead.

One will easily understand this if one imagines, for instance, a white or colored precipitate which is produced by mixing two liquids; it is formed either at once or after some time, it is cloudy or of a curdy or gelatinous character, sandy or crystalline, dull or bright, it deposits easily or slowly, etc.; or if it is colored it has a certain tint. Among

the countless white precipitates each has something peculiar to itself; and when one has experience in this sort of appearances, whatever one sees during an investigation at once awakens the remembrance of what one has seen. The following example will make clear what I mean by sight or eye memory. During our joint research on uric acid, Wöhler one day sent me a crystalline body which he had obtained by the action of peroxide of lead upon this acid. I immediately thereupon wrote to him with great joy, and, without having analyzed the body, that it was allantoin. Seven years before I had had this body in my hands; it had been sent to me by C. Gmelin for investigation, and I had published an analysis of it in Poggendorff's *Annalen;* since that time I had not seen it again. But when we had analyzed the substance obtained from uric acid there appeared a difference in the amount of carbon, the new body gave 1½ per cent carbon less, and since the nitrogen had been determined by the qualitative method a corresponding quantity (4 per cent) of nitrogen more; consequently it could not possibly be allantoin. However, I trusted my eye memory more than my analysis, and was quite sure that it was allantoin, and the thing now to be done was to find the remains of the substance previously analyzed in order to analyze it afresh. I could describe the little glass in which it was with such precision that my assistant at last succeeded in picking it out from amongst a couple of thousand other preparations. It looked exactly like our new body, except that examination under the lens showed that Gmelin, in the preparation of his allantoin, had purified it with animal charcoal, some of which having passed through the paper in the filtration had become mixed with the crystals.

Without the complete conviction which I had that the two bodies were identical, the allantoin produced artificially from uric acid would undoubtedly have been regarded as a new body, and would have been designated by a new name, and one of the most interesting relations of uric acid to one of the constituents of the urine of the fœtus of the cow would perhaps have remained for a long time unobserved.

In this manner it came to pass that everything I saw remained intentionally or unintentionally fixed in my memory with equal photographic fidelity. At a neighboring soap boiler's I saw the process of boiling soap, and learned what "curd soap" and "fitting" are, and how white soap is made; and I had no little pleasure when I succeeded in showing a piece of soap of my own making, perfumed with oil of turpentine. In the workshop of the tanner and dyer, the smith and brass founder, I was at home and ready to do any hand's turn.

In the market at Darmstadt I watched how a peripatetic dealer in odds and ends made fulminating silver for his pea-crackers. I observed the red vapors which were formed when he dissolved his silver, and that he added to it nitric acid; and then a liquid which smelled of brandy, and with which he cleaned dirty coat collars for the people.

With this bent of mind it is easy to understand that my position at

school was very deplorable; I had no ear memory, and retained nothing or very little of what is learned through this sense; I found myself in the most uncomfortable position in which a boy could possibly be; languages and everything that is acquired by their means, that gains praise and honor in the school were out of my reach; and when the venerable rector of the gymnasium (Zimmermann), on one occasion of his examination of my class, came to me and made a most cutting remonstrance with me for my want of diligence, how I was the plague of my teachers and the sorrow of my parents, and what did I think was to become of me, and when I answered him that I would be a chemist, the whole school and the good old man himself broke into an uncontrollable fit of laughter, for no one at the time had any idea that chemistry was a thing that could be studied.

Since the ordinary career of a gymnasium student was not open to me, my father took me to an apothecary at Heppenheim, in the Hessian Bergstrasse; but at the end of ten months he was so tired of me that he sent me home again to my father. I wished to be a chemist, but not a druggist. The ten months sufficed to make me completely acquainted alike with the use and the manifold applications of the thousand and one different things which are found in a druggist's shop.

Left to myself in this way, without advice and direction, I completed my sixteenth year, and my persistent importunity at last induced my father to give me permission to go to the University of Bonn; whence I followed to Erlangen the professor of chemistry, Kastner, who had been called to the Bavarian University. There arose at that time at the newly-established University of Bonn an extraordinary quickening of scientific life: but the degenerate philosophical methods of investigation, as they had been embodied in Oken, and still worse in Wilbrand, had a most pernicious influence on the branches of natural science, for it had led alike in lecture and in study to a want of appreciation of experiment and of unprejudiced observation of nature, which was ruinous to many talented young men.

From the professional chair the pupil received an abundance of ingenious contemplations; but, bodiless as they were, nothing could be made of them.

The lectures of Kastner, who was considered a most eminent chemist, were without order, illogical, and arranged just like the jumble of knowledge which I carried about in my head. The relations which he discovered between phenomena were somewhat after the following pattern:

"The influence of the moon upon the rain is clear, for as soon as the moon is visible the thunder-storm ceases," or "the influence of the sun's rays on water is shown by the rise of the water in the shafts of mines, some of which can not be worked in the height of summer." That we see the moon when the thunderstorm is dispelled, and that

the water rises in the mine when the brooks which drive the pumps dry up in summer, was, of course, too blunt an explanation for a clever lecture.

It was then a very wretched time for chemistry in Germany. At most of the universities there was no special chair for chemistry; it was generally handed over to the professor of medicine, who taught it, as much as he knew of it, and that was little enough, along with the branches of toxicology, pharmacology, materia medica, practical medicine, and pharmacy.

Many years after this in Giessen, descriptive and comparative anatomy, physiology, zoology, natural history, and botany were in one single hand.

While the labors of the great Swedish chemist, the English and French natural philosophers, Humphry Davy, Wollaston, Biot, Arago, Fresnel, Thenard, and Dulong opened up entirely new spheres of investigation, all these inestimable acquisitions found no soil in Germany where they could bear fruit. Long years of war had undermined the well-being of the people, and external political pressure had brought in its train the desolation of our universities, filled men with painful anxiety for many years, and turned their desires and their strength in other directions. The national spirit had asserted its freedom and independence in ideal spheres, and by the destruction of belief in authority had brought rich blessings in many ways,—for example, in medicine and philosophy; only in physiology it had broken through its natural limits and wandered far beyond experience.

The goal of science and the fact that it has value only when it is useful to life had almost dropped out of sight, and men amused themselves in an ideal world which had no connection with the real one. It was considered an almost debasing sentiment, and one unworthy of an educated person, to believe that in the body of a living being the crude and vulgar inorganic forces played any part. Life and all its manifestations and conditions were perfectly clear. Natural phenomena were clothed in bewitchingly lovely dress, cut out and fitted by clever men, and this was called philosophical investigation. Experimental instruction in chemistry was all but extinct at the universities, and only the highly-educated pharmacists, Klaproth, Hermbstädt, Valentin Rose, Trommsdorff, and Buchholz had themselves preserved it, but in another department.

I remember at a much later period, Prof. Wurzer, who held the chair of chemistry at Marburg, showing me a wooden table drawer, which had the property of producing quicksilver every three months. He possessed an apparatus which mainly consisted of a long clay pipe stem, with which he converted oxygen into nitrogen by making the porous pipe stem red hot in charcoal, and passing oxygen through it.

Chemical laboratories, in which instruction in chemical analysis was imparted, existed nowhere at that time. What passed by that name

were more like kitchens filled with all sorts of furnaces and utensils for the carrying out of metallurgical or pharmaceutical processes. No one really understood how to teach it.

I afterwards followed Kastner to Erlangen, where he had promised to analyze some minerals with me; but unfortunately he did not himself know how to do it, and he never carried out a single analysis with me.

The benefit which I gained through intercourse with other students during my sojourn in Bonn and Erlangen was the discovery of my ignorance in very many subjects which they brought with them from school to the university, and since I got nothing to do in chemistry I laid out all my energies to make up for my previously neglected school studies.

In Bonn and Erlangen small numbers of students joined with me in a chemico-physical union, in which every member in turn had to read a paper on the question of the day, which, of course, consisted merely in a report on the subjects of the essays which appeared monthly in Gilbert's *Annalen* and Schweigger's *Journal*.

In Erlangen, Schelling's lectures attracted me for a time, but Schelling possessed no thorough knowledge in the province of natural science, and the dressing up of natural phenomena with analogies and in images, which was called exposition, did not suit me.

I returned to Darmstadt fully persuaded that I could not attain my ends in Germany.

The dissertations of Berzelius—that is to say, the better translation of his handbook, which had a large circulation at that time—were as springs in the desert.

Mitscherlich, H. Rose, Wöhler, and Magnus had then repaired to Berzelius, in Stockholm; but Paris offered me means of instruction in many other branches of natural science, as, for instance, physics, such as could be found united in no other place. I made up my mind to go to Paris. I was then seventeen and a-half years old. My journey to Paris, the way and manner in which I came in contact with Thenard, Humboldt, Dulong, and with Gay-Lussac, and how the boy found favor in the sight of those men, borders on the fabulous, and would be out of place here. Since then it has frequently been my experience that marked talent awakens in all men, I believe I may say without exception, an irrepressible desire to bring about its development. Each helps in his own way, and all together as if they were acting in concert; but talent only compels success if it is united with a firm indomitable will. External hindrances to its development are in most cases very much less than those which lie in men themselves; for just as no one of the forces of nature, however mighty it may be, ever produces an effect by itself alone, but always only in conjunction with other forces, so a man can only make valuable that which he learns without trouble, or acquires readily, for which as we say, he has a natural gift, if he learns

many other things in addition, which perhaps cost him more trouble to acquire, than they cost other people.

Lessing says that talent really is will and work, and I am very much inclined to agree with him.

The lectures of Gay-Lussac, Thenard, Dulong, etc., in the Sorbonne, had for me an indescribable charm; the introduction of astronomical or mathematical method into chemistry, which changes every problem when possible into an equation, and assumes in every uniform sequence of two phenomena a quite certain connection of cause and effect, which, after it has been searched for and discovered, is called "explanation" or "theory," had led the French chemists and physicists to their great discoveries. This kind of "theory" or "explanation" was as good as unknown in Germany, for by these expressions was understood not something "experienced," but always something which man must add on, and which he fabricates.

French exposition has, through the genius of the language, a logical clearness in the treatment of scientific subjects very difficult of attainment in other languages, whereby Thenard and Gay-Lussac acquired a mastery in experimental demonstration. The lecture consisted of a judiciously arranged succession of phenomena,—that is to say, of experiments, whose connection was completed by oral explanations. The experiments were a real delight to me, for they spoke to me in a language I understood, and they united with the lecture in giving definite connection to the mass of shapeless facts which lay mixed up in my head without order or arrangement. The anti-phlogistic or French chemistry had, it is true, brought the history of chemistry before Lavoisier to the guillotine; but one observed that the knife only fell on the shadow, and I was much more familiar with the phlogistic writings of Cavendish, Watt, Priestly, Kirwan, Black, Scheele, and Bergmann, than with the anti-phlogistic; and what was represented in the Paris lectures as new and original facts appeared to me to be in the closest relation to previous facts, so much so, indeed, that when the latter were imagined away the others could not be.

I recognized or (more correctly perhaps), the consciousness dawned upon me, that a connection in accordance with fixed laws exists not only between two or three, but between all chemical phenomena in the mineral, vegetable, and animal kingdoms; that no one stands alone, but each being always linked with another, and this again with another, and so on, all are connected with each other, and that the genesis and disappearance of things is an undulatory motion in an orbit.

What impressed me most in the French lectures was their intrinsic truth, and the careful avoidance of all pretense in the explanations; it was the most complete contrast to the German lectures, in which the whole scientific teaching had lost its solid construction through the preponderance of the deductive method.

An accidental occurrence drew A. von Humboldt's attention to me in Paris, and the interest which he took in me induced Gay-Lussac to complete in conjunction with me a piece of work which I had begun.

In this manner I had the good fortune to enjoy the closest intercourse with the great natural philosopher; he worked with me as he had formerly worked with Thenard; and I can well say that the foundation of all my later work and of my whole course was laid in his laboratory in the arsenal.

I returned to Germany, where, through the school of Berzelius, H. Rose, Mitscherlich, Magnus, and Wöhler, a great revolution in inorganic chemistry had already commenced. Through the support of von Humboldt's warm recommendation, an extraordinary professorship of chemistry at Giessen was conferred upon me in my twenty-first year.

My career in Giessen commenced in May, 1824. I always recall with pleasure the twenty-eight years which I spent there; it was as if Providence had led me to the little university. At a larger university, or in a larger place, my energies would have been divided and dissipated, and it would have been much more difficult, and perhaps impossible, to reach the goal at which I aimed, but at Giessen everything was concentrated in work, and in this I took passionate pleasure.

The need for an institution in which the students could be instructed in the art of chemistry, by which I mean familiarity with chemical analytical operations, and skill in the use of apparatus, was then being felt; and hence it happened that on the opening of my laboratory for teaching analytical chemistry and the methods of chemical research, students by degrees streamed to it from all sides. As the numbers increased I had the greatest difficulty with the practical teachings itself. In order to teach a large number at one time it was necessary to have a systematic plan, or step by step method, which had first to be thought out and put to the proof.

The manuals which several of my pupils have published later (Fresenius and Will) contain essentially, with little deviation, the course which was followed at Giessen; it is now familiar in almost every laboratory.

The production of chemical preparations was an object to which I paid very particular attention; it is very much more important than is usually believed, and one can more frequently find men who can make very good analyses than such as are in a position to produce a pure preparation in the most judicious way. The formation of a preparation is an art, and at the same time a qualitative analysis, and there is no other way of making one's self acquainted with the various chemical properties of a body than by first producing it out of the raw material and then converting it into its numerous compounds and so becoming acquainted with them.

By ordinary analysis one does not learn by experience what an important means of separation crystallization is in skillful hands; and

just as little the value of an acquaintance with the peculiarities of different solvents. Consider only an extract of a plant or of flesh which contains half a dozen crystalline bodies in very small quantities embedded in extraneous matter, which almost entirely masks the properties of the others; and yet, in this magma, we can recognize by means of chemical reactions the peculiarities of every single body in the mixed mass, and learn to distinguish what is a product of decomposition and what is not, in order to be able to separate them afterwards by means which will exert no decomposing influence. An example of the great difficulty of finding the right way in such researches is afforded by the analysis of bile by Berzelius. Of all the numerous substances which he has described as its constituents no one is, properly speaking, contained in the natural bile.

An extremely short time had been sufficient for the famous pupils of the Swedish master to give a wonderful degree of perfection to mineral analysis which depends on an accurate knowledge of the properties of inorganic bodies; their compounds and their behavior to each other were studied in all directions by the Swedish school with a keenness quite unusual previously and even now unsurpassed. Physical chemistry, which investigates the uniform relations between physical properties and chemical composition, had already gained a firm foundation by the discoveries of Gay-Lussac and von Humboldt, on the combining proportions of bodies in the gaseous state, and those of Mitscherlich, on the relations between crystalline form and chemical composition; and in chemical proportions the structure appeared to have received its coping-stones and to stand forth completed. All that foreign countries had acquired in bygone times in the way of discoveries now yielded rich fruit also in Germany.

Organic chemistry—or what is now called organic chemistry—had then no existence. It is true that Thenard and Gay-Lussac, Berzelius, Prout, and Döbereiner had already laid the foundations of organic analysis, but even the great investigations of Chevreul upon the fatty bodies excited but little attention for many years. Inorganic chemistry demanded too much attention, and, in fact, monopolized the best energies.

The bent which I acquired in Paris was in a quite different direction. Through the work which Gay-Lussac had done with me upon fulminating silver I was familiar with organic analysis, and I very soon saw that all progress in organic chemistry depended essentially upon its simplification; for in this branch of chemistry one has to do not with different elements which can be recognized by their peculiar properties, but always with the same elements whose relative proportions and arrangement determine the properties of organic compounds.

In organic chemistry an analysis is necessary to do that for which a reaction suffices in inorganic chemistry.

The first years of my career in Giessen I devoted almost exclusively to the improvement of the methods of organic analysis, and the immediate result was that there began at this little university an activity which had never before been seen.

For the solution of innumerable questions connected with plants and animals, on their constituents, and on the reactions accompanying their transformation in the organism, a kindly fate brought together the most talented young men from all the countries of Europe, and any one can imagine what an abundance of facts and experiences I gained from so many thousands of experiments and analyses, which were carried out every year, and for so many years, by twenty and more indefatigable and skilled young chemists.

Actual teaching in the laboratory, of which practiced assistants took charge, was only for the beginners; the progress of my special students depended on themselves. I gave the task and supervised the carrying out of it, as the radii of a circle have all their common center. There was no actual instruction; I received from each individual every morning a report upon what he had done on the previous day, as well as his views on what he was engaged upon. I approved or made my criticisms. Every one was obliged to follow his own course. In the association and constant intercourse with each other, and by each participating in the work of all, every one learned from the others. Twice a week, in winter, I gave a sort of review of the most important questions of the day; it was mainly a report on my own and their work combined with the researches of other chemists.

We worked from break of day till nightfall. Dissipations and amusements were not to be had at Giessen. The only complaint, which was continually repeated, was that of the attendant (Aubel), who could not get the workers out of the laboratory in the evening, when he wanted to clean it.

The remembrance of this sojourn at Giessen awakened in most of my pupils, as I have frequently heard, an agreeable sense of satisfaction for well-spent time.

I had the great good fortune, from the commencement of my career at Giessen, to gain a friend of similar tastes and similar aims, with whom, after so many years, I am still knit in the bonds of warmest affection.

While in me the predominating inclination was to seek out the points of resemblance in the behavior of bodies or their compounds, he possessed an unparalleled faculty of perceiving their differences. A keenness of observation was combined in him with an artistic dexterity, and an ingeniousness in discovering new means and methods of research or analysis such as few men possess.

The achievement of our joint work upon uric acid and oil of bitter almonds has frequently been praised; it was his work. I can not sufficiently highly estimate the advantage which the association with Wöhler

brought to me in the attainment of my own as well as our mutual aims, for by that association were united the peculiarities of two schools—the good that was in each became effective by co-operation. Without envy and without jealousy, hand in hand, we pursued our way; when the one needed help, the other was ready. Some idea of this relationship may be obtained if I mention that many of our smaller pieces of work which bear our joint names were done by one alone; they were charming little gifts which one presented to the other.

After sixteen years of the most laborious activity I collected the results gained, so far as they related to plants and animals, in my "Chemistry Applied to Agriculture and Physiology," two years later in my "Animal Chemistry," and the researches made in other directions in my "Chemical Letters." The last-mentioned was generally received as a popular work, which, to those who study it more closely, it really is not, or was not at the time when it appeared.

Mistakes were made, not in the facts, but in the deductions about organic reactions; we were the first pioneers in unknown regions, and the difficulties in the way of keeping on the right path were sometimes insuperable.

Now, when the paths of research are beaten roads, it is a much easier matter; but all the wonderful discoveries which recent times have brought forth were then our own dreams, whose realization we surely and without doubt anticipated.

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Here the manuscript ends, and it is to be hoped that more of it will yet be found. Liebig's reference to Wöhler is very touching, and shows a side of his character which all his pupils knew well; they tell many genial stories illustrating his unselfishness and kindness of heart. One could have wished that he had not considered the stories "bordering on the fabulous," of how he "found favor in the sight of Humboldt, Gay-Lussac, and Thenard, out of place here." They would have been far from out of place. Mr. Muspratt supplies one of these stories as he heard it from Liebig's own lips, in the Münich Laboratory, as follows:

Liebig frequently spoke, in most grateful terms, of the kind manner in which he—a youth barely eighteen—was received by Gay-Lussac, Thenard, and other eminent chemists, in Paris.

In the summer of 1823 he gave an account of his analysis of fulminating silver before the Academy. Having finished his paper, as he was packing up his preparations, a gentleman came up to him and questioned him as to his studies and future plans, and after a most exacting examination, ended by asking him to dinner on the following Sunday. Liebig accepted the invitation, but, through nervousness and confusion, forgot to ask the name and address of his interviewer. Sunday came, and poor Liebig was in despair at not being able to keep his engagement.

The next day a friend came to him, and said, "What on earth did

you mean by not coming to dine with von Humboldt yesterday, who had invited Gay-Lussac and other chemists to meet you?" "I was thunderstruck," said Liebig, "and rushed off, as fast as I could run, to von Humboldt's lodgings, and made the best excuses I could." The great traveller, satisfied with the explanation, told him it was unfortunate, as he had several members of the Academy at his house to meet him, but thought he could make it all right if he would come to dinner next Sunday. He went, and there made the acquaintance of Gay-Lussac, who was so struck with the genius and enthusiasm of the youth that he took him into his private laboratory, and continued, in conjunction with him, the investigation of the fulminating compounds.

# DIVERGENT EVOLUTION THROUGH CUMULATIVE SEGREGATION.*

By Rev. John Thomas Gulick.

## INTRODUCTION.

In my study of Sandwich Island terrestrial mollusks, my attention was early arrested by the fact that wide diversity of allied species occurs within the limits of a single island and in districts which present essentially the same environment. As my observations extended I became more and more impressed with the improbability that these divergences had been caused by differences in the environment. It was not easy to prove that sexual selection had no influence; but, owing to the very low grade of intelligence possessed by the creatures, it seemed impossible that the form and coloring of the shells should be the result of any such process. I was therefore led to search for some other cause of divergent transformation, the diversity of whose action is not dependent on differences in nature external to the organism.

I found strong proof that there must be some such principle, not only in the many examples of divergence under uniform activities in the environment, but in the fact that the degrees of divergence between nearly allied forms are roughly measured by the number of miles by which they are separated, and in the fact that this correspondence between the ratios of distance and the ratios of divergence is not perceptibly disturbed by passing over the crest of the island into a region where the rainfall is much heavier, and still further in the fact that the average size of the areas occupied by the species of any group varies, as we pass from group to group, according as the habits of the group are more or less favorable to migration. I perceived that these facts could all be harmonized by assuming that there is some cause of divergence more constant and potent than differences in nature external to the organism, and that the influence of this cause was roughly measured by the time and degree of separation.

During the summer of 1872, I prepared two papers, in which these facts and opinions were presented. One of these, entitled "The Vari-

* [Read December 15, 1887.] From *The Journal of Zoölogy of the Linnean Society*, September, 1888, vol. XX, pp. 189–274.

ation of Species as Related to their Geographical Distribution, illustrated by the Achatinellinæ," was published in *Nature* for July 18, 1872; the other, entitled "Diversity of Evolution under One Set of External Conditions," after being read before the British Association for the Advancement of Science in August, 1872, was, through the kindness of Mr. Alfred Wallace, brought before the Linnean Society, and was finally published in the *Linnean Society's Journal*, *Zoölogy*, vol. XI, pp. 496–505.

In the former paper I used the following words in calling attention to the impossibility of explaining the origin and distribution of these forms by natural selection: "Whether we call the different forms species or varieties, the same questions are suggested as to how they have arisen and as to how they have been distributed in their several localities. In answering these questions, we find it difficult to point to any of those active causes of accumulated variation, classed by Darwin as natural selection. - - - There is no reason to doubt that some varieties less fitted to survive have disappeared; but it does not follow that the 'survival of the fittest' (those best fitted when compared with those dying prematurely, but equally fitted when compared with each other) is the determining cause which has led to these three species being separated from each other in adjoining valleys. *The 'survival of the fittest' still leaves a problem concerning the distribution of those equally fitted.* It can not be shown that the 'survival of the fittest' is at variance with the survival, under one set of external circumstances, of varieties differing more and more widely from each other in each successive generation. The case of the species under consideration does not seem to be one in which difference of environment has been the occasion of different forms being preserved in the different localities. It is rather one in which varieties resulting from some other cause, though equally fitted to survive in each of the localities, have been distributed according to their affinities in separate localities."

In the latter paper I raised the following questions concerning natural selection. "The terms 'natural selection' and 'survival of the fittest' - - - imply that there are variations that may be accumulated according to the differing demands of external conditions. What, then, is the effect of these variations when the external conditions remain the same? Or can it be shown that there is no change in organisms that is not the result of change in external conditions? Again, if the initiation of change in the organism is through change in the environment, - - - *does the change expend itself in producing from each species just one new species* completely fitted to the conditions, *or may it produce from one stock many that are equally fitted?*" (p. 497). In answering these questions I called "attention to the variation and distribution of terrestrial mollusks, more especially those found on the Sandwich Islands," and gave what seemed to me strong reasons for believing that "*the evolution of these different forms can not be attrib-*

*uted to difference in their external conditions.* - - - If we would account for the difference and the limited distribution of these allied forms on the hypothesis of evolution from one original species, *it seems to me necessary to suppose two conditions, separation and variation.* I regard *separation* as a condition of the species and not of surrounding nature, because it is a state of division in the stock which *does not necessarily imply any external barriers, or even the occupation of separate districts. This may be illustrated by the separation between the castes of India, or between different genera occupying the same locality.* - - - We must suppose that they [the diverging forms] must possess an inherent tendency to variation so strong that *all that is necessary to secure a divergence of types* in the descendants of one stock *is to prevent*, through a series of generations, *their intermingling* with each other to any great degree" (pp. 498, 499). I also called attention to the fact that some forms of natural selection must "prevent variation and give a wider diffusion to forms that would otherwise be limited in their range and variable in their type. Natural selection is as efficient in producing permanence of type in some cases as in accelerating variation in other cases" (p. 504). On page 499 I pointed out the law that "the area occupied by any species must vary directly as its power and opportunity for migration, and inversely as its power of [divergent] variation." And on page 505 I gave a brief summary of my reasons for believing that "*separation without a difference of external circumstances is a condition sufficient to ensure* - - - *divergence in type.*"

Subsequent investigation has led to the development of my theory, with a fuller discussion of the causes and laws that are revealed in these phenomena. In an article published in *The Chrysanthemum* (Yokohama and London, Trübner & Co.), January, 1883, I state my belief "that the quality, the diversity, and the rapidity of the variation depend chiefly upon the nature of the organism; and that while the nature of the external conditions has power to winnow out whatever forms are least fitted to survive, *there will usually remain a number of varieties equally fitted to survive;* and that *through* the *law of segregation* constantly operating in species distributed over considerable areas, *these varieties continue to diverge* both in form and in habits till separate species are fully established, though the conditions are the same throughout the whole area occupied by the diverging forms." The conclusion reached was that "The theory that diversity of natural selection is, like variation, an essential factor in producing diversity of species, is untenable. On the contrary, we find that diversity of natural selection is not necessary to diversity of evolution, nor uniformity of natural selection to uniformity of evolution; but while *variation and separation are the essential factors in diversity*, and intercrossing and unity of descent the essential agents in uniformity of *evolution*, natural selection may be an important ally on either side."

In an article on "Evolution in the Organic World," published in

*The Chinese Recorder* (Shanghai), July, 1885, I use the following language: "We see what natural selection can not explain by considering the nature of the process. The survival of the fittest results in the separate breeding of the fittest, and therefore in the increasing fitness of successive generations of survivors; *but how can it account for the division of the survivors of one stock, occupying one country, into forms differing more and more widely from each other? To explain such a result we must find some other law. I am prepared to show that there is such a law arising out of the very nature of organic activities, a law of segregation, bringing together those similarly endowed and separating them from those differently endowed.*"

Without variation there can be no segregate breeding; and without segregate breeding and heredity there can be no accumulation of divergent variations resulting in the formation of races and species. In producing divergent evolution the causes of variation and heredity are therefore as important as the causes of segregate breeding; and though I pass them by in my present discussion, I trust it will not be attributed to an under-estimate of their importance. Though I do not stop to discuss the causes of variation, my reasoning rests on the observed fact that in every deparment of the organic world variation is found, and that in the vast majority of cases, if not absolutely in all, the diversities to which any freely inter-generating group of organisms is subject follow the general law of "frequency of deviation from an average." As this is a law according to which half of the members of the inter-generating group are above and half below the average in relation to any character, there must often occur simultaneous variation of several individuals in some character which tends to produce segregate breeding. The reality and importance of this law is not at all dependent on the reality of any of the theories of heredity and variation that are now being discussed. Whatever may be the causes that produce variation, whether they depend entirely upon changes in external conditions or are chiefly due to changing activities in the organism and the hereditary effects of acquired characters, or are (as Weismann maintains) the direct result of sexual reproduction which never transmits acquired characters—in any and every case this law of deviation from an average remains undisturbed and is recognized as an important factor in the present paper. It therefore can not be urged that the theory here advanced assumes simultaneous variation without any ground for making such an assumption; nor can it be said that it rests on the incredible assumption that chance variation of very rare kinds will be duplicated at one time and place and will represent both sexes.

Moritz Wagner first discussed what he calls "The law of the migration of organisms," in a paper read before the Royal Academy of Sciences at Munich, in March, 1868; but my attention was not called to it till after the reading of my paper before the British Association in August, 1872. In a fuller paper entitled "The Darwinian Theory

and the Law of the Migration of Organisms," an English translation of which was published by Edward Stanford (London, 1873), the same author maintains that "the constant tendency of individuals to wander from the station of their species is absolutely necessary for the formation of races and species" (p. 4). "The migration of organisms and their colonization are, according to my conviction, a necessary condition of natural selection" (p. 5). On pages 66 and 67 he expands the same statement, and objects to Darwin's view "that on many large tracts all individuals of the same species have become gradually changed." Again, he contends that "transformation is everywhere and always dependent on isolation in order to have lasting effect. Without separation from the home of the species, this wonderful capacity would be completely neutralized" (p. 74). "Natural selection is not in itself an unconditional necessity, but is dependent on migration and geographical isolation during a long period, together with altered conditions of life" (p. 57). "Where there is no migration, that is, where no isolated colony is founded, natural selection can not take place" (p. 59).

A comparison of his paper with my two papers published in 1872, already referred to, will show several fundamental differences in the two theories. He maintains that—

(1) The separation of a few individuals from the rest of the species is absolutely necessary for the operation of natural selection, and therefore for any transformation of the species, no matter how great the change of conditions may be in the original home of the species.

(2) Migration and geographical barriers are the only effectual causes, independent of human action, by which a few individuals can be separated from the rest of the species, and are therefore necessary to the transformation of species.

(3) Exposure to a new form of natural selection is a necessary condition for any transformation of a species.

(4) Difference of external conditions is necessary to difference of natural selection, and therefore necessary to any transformation of species.

(5) Geographical isolation and altered conditions of life are necessary conditions for natural selection, as that is for the modification of species.

(6) The separation of which he speaks is the entering of a few individuals into a new territory, where the conditions are different from those in the old habitat, and where the body of the species fail of reaching them.

My chief positions were the following, in strong contrast with the foregoing—

(1) Separate generation is a necessary condition for divergent evolution, but not for the transformation of all the survivors of a species in one way.

(2) "Separation does not necessarily imply any external barriers, or even the occupation of separate districts."

(3) Diversity of natural selection is not necessary to diversity of evolution.

(4) Difference of external conditions is not necessary to diversity of evolution.

(5) "Separation and variation," that is, variation not overwhelmed by crossing, "is all that is necessary to secure a divergence of types in the descendants of one stock," though external conditions remain the same, and though the separation is other than geological.

(6) The separation of which I speak is anything, in the species or in the environment, that divides the species into two or more sections that do not freely inter-cross, whether the different sections remain in the original home or enter new and dissimilar environments.

Though these propositions were very briefly and imperfectly presented, I am not aware that any better statement of the facts of segregation had been previously published.

The present paper is the result of a long-continued endeavor to understand the relations in which this factor stands to natural selection and the other causes that co-operate in producing divergent evolution; and though my work has been done under the great disadvantage of entire separation from libraries and from other workers in similar lines, I trust it may contribute something towards the elucidation of the subject. In expanding my theory I have been unable to make any use of the positions taken in Moritz Wagner's paper, as they seem to me very extreme and far removed from the facts of nature. The two theories correspond chiefly in that they discuss the relation of separation to the transformation of species, while the explanations given of the nature, causes, and effects of separation widely differ. I am informed that my paper on "Diversity of evolution under one set of external conditions" was translated and circulated in Germany; but whether it had any effect in modifying Wagner's theory I have not the means of knowing.

I have recently discovered that the principle of segregate breeding, which I have found to be of such importance in the evolution of species, is allied to the law of segregation propounded by Spencer in his "First Principles." By direct consideration of the conditions that have been found necessary for the development of divergent races of domestic plants and animals I have discovered segregate breeding as a necessary condition for divergent evolution, and by direct observation on the propagation of plants and animals under natural conditions I have discovered cumulative segregation as a constant result from certain forms of activity in the organism when dealing with a complex environment. It is therefore with special pleasure that I observe that a law of very similar import may be derived by a wholly different method from the general laws of action and reaction in the physical world. It should, however, be noticed that in the brief references made to the subject in Spencer's

"Principles of Biology"* it is assumed that "increasingly definite distinctions among variations are produced wherever there occur definitely-distinguished sets of conditions to which the varieties are respectively subject," and only where these occur; for "Vital actions remain constant so long as the external actions to which they correspond remain constant"; and no reference is anywhere made to the principle that whatever causes sexual separation between dissimilar members of one family, race, or species tends not only to perpetuate, but to increase their dissimilarity in the succeeding generations. The view maintained in the following paper is I believe in better accord with the fundamental principle that "Unlike units of an aggregate are sorted into their kinds and parted when uniformly subject to the same incident forces,"† as is also the teaching of Spencer's "Principles of Biology," in one passage; for I have recently discovered that in a single paragraph of this work it is maintained that while exposed to the same external conditions, the members of the same species may be increasingly differentiated, "until at length the divergence of constitutions and modes of life become great enough to lead to segregation of the varieties."‡ If the segregation had been introduced as a necessary condition without which the divergence of families and races could not take place, the position taken in this paragraph would have been essentially the same as the one I have adopted. In the next section, however, he abandons the position, using the following words: "Through the process ot differentiation and integration, which of necessity brings together, or keeps together, like individuals, and separates unlike ones from them, *there must nevertheless be maintained a tolerably uniform species, so long as there continues a tolerably uniform set of conditions in which it may exist.* [The italics are mine.]

I trust my endeavor to contribute something toward the development of the theory of divergent evolution will not be attributed to any lack of appreciation of what has already been accomplished. The propounders of a doctrine which has profoundly influenced every department of modern thought need no praise from me; but as their theory is confessedly incomplete, and as one of the leaders in the movement has called attention to the need of a re-discussion of the fundamental factors of evolution, I offer my suggestions and amendments after prolonged and careful study.

### PHYSIOLOGICAL SELECTION AND SEGREGATE FECUNDITY.

The abstract of Mr. Romanes's paper on "Physiological selection," given in *Nature* August 5, 12, and 19, 1886, did not come into my hands till the following January, when my theory of divergent evolution through cumulative segregation, which had been gradually developing

*Compare §§ 91, 156, 169, 170

† See Spencer's "First Principles", § 166, near the end; also a fuller statement in § 169.

‡ See *ibid.*, § 90.

since the publication of my paper on "Diversity of evolution under one set of external conditions," was for the most part written out in its present form. Since then, and with reference to the discussion on physiological selection, I have worked out the algebraic formulas given in the last chapter, and have introduced explanations of the same; but at the same time I have removed several chapters in which the principle of selection was discussed at length, and have endeavored to bring the whole within a compass that would allow of its being published by some scientific society. In order to attain this end, I reserve for another occasion a discussion of the principles of intensive segregation, under which name I class the different ways in which other principles combine with segregation in producing divergent evolution.

It was my intention to bring together examples of the different forms of Segregation discussed, that they might be published with the theoretical part; but the large number of pages found necessary for even the briefest presentation of the principles involved, and the fact that Mr. Romanes's paper has appeared relating to some of the same problems, leads me to present the results of my studies without further delay. The facts on which large portions of my theory rest are of the most familiar kind, and no additional light would be gained though their numbers were multiplied a hundredfold. Indeed, one of the marked features of my theory is that in its chief outlines it rests on facts that are universally acknowledged. The aim of the theory is to show the connection of these facts with divergent evolution.

Though many divergencies appear in our method of treating the subject, the fundamental theory underlying my segregate fecundity and Mr. Romanes's Physiological Selection seems to be very similar, if not the same. The most important differences I have noticed are, (1) that he seems to regard mutual sterility as sufficient to account for the separate propagation of species and varieties thus characterized, without calling in the aid of any other form of segregation, while I regard it as a negative form of segregation that would result in the general destruction of all life if not associated with what I call positive forms of segregation; and (2) that he maintains that "Physiological selection is almost exclusively a theory of the origin of species, seeing that it can but very rarely have had anything to do with the formation of genera, and can never have had anything at all to do with the formation of families, orders, or classes. Hence the evidence which we have of the evolutionary influence of physiological selection, unlike that which we have of the evolutionary influence of natural selection, is confined within the limits of specific distinctions,"* while I maintain that segregation of some form is a necessary condition for all divergent evolution, and that in fact segregate fecundity in many cases prevents the inter-crossing of divergent forms that, though descended from a common stock, now belong to different families and orders.

* *Linn. Soc. Journ., Zoölogy,* vol. XIX, p. 396.

The first of these differences, though of considerable importance, is I think due to the method of presentation rather than to any fundamental discrepancy in the theories. The positive forms of segregation are I judge assumed to be present, though their co-operation is not distinctly recognized as a necessary condition for the breeding of forms that are mutually sterile.

I must, however, confess that I do not see how to reconcile his statement that "Physiological selection can never have had anything at all to do with the formation of families, orders, or classes" with what I believe to be the facts concerning Segregate Fecundity; and if physiological selection is to be understood as including Seasonal and perhaps other forms of Segregation, this passage seems to be still more opposed to the principles of divergent evolution as I understand them. He certainly could not have intended to say that mutual fertility between allied genera not otherwise segregated would not have stood in the way of their becoming different families, and that, therefore, mutual sterility has had nothing to do with their continued divergence; still he seems to have failed to perceive the important influence this principle must have had on the divergent evolution of the higher groups of organisms.

The correspondences in the two papers are, notwithstanding, more remarkable than the differences. Of these, the most conspicuous is the use of the word segregation to express the principle under consideration.* As I have already pointed out, I used this word for the same purpose in an article in the *Chrysanthemum*, published in January, 1883; and again in the *Chinese Recorder* for July, 1855, where I spoke of the "law of segregation rising out of the very nature of organic activities, bringing together those similarly endowed," and causing "the division of the survivors of one stock, occupying one country, into forms differing more and more widely from each other."

I trust that my discussion of the various forms of segregation, both negative and positive, though presented in so condensed a form, will throw light on the subject of the mutual sterility of species; and that in other ways my presentation of the subject will contribute something, not only to the theory of physiological *segregation* but to other branches of the general theory of evolution.

I should here acknowledge (what will, I think, be manifest on every page of my paper) that my obligations to Darwin and Wallace are far greater than are indicated by quotations and references.

I very much regret that I have failed of obtaining a copy of "Evolution without Natural Selection," by Charles Dixon; but, from his letter in *Nature*, vol. XXXIII, p. 100, I see that he maintains "That isolation can preserve a non-beneficial variation as effectually as natural selection can preserve a beneficial variation." He does not there refer to the fact,

*See paper on "Physiolgical Selection," *Linn. Soc. Journ. Zoölogy*, vol. XIX, pp. 354, 356, 391, 395.

which I emphasize, that all divergence of a permanent character, whether beneficial or non-beneficial, is dependent on se-generation, either separative or segregative.

PRELIMINARY DEFINITIONS.

Believing that great obscurity has often been introduced into the discussion of biological subjects by the use of terms of uncertain import, I have endeavored to obtain greater precision by giving definitions of the terms I have introduced; and for the sake of indicating what words are thus used with special and definite meanings, they have been distinguished by capitals. A few of these definitions are here given, and others will be given in the body of the paper.

*An Inter-generant*, or *Inter-generating Group*, is a group of individuals so situated and so endowed that they freely cross with each other.

*Se-generation*, or *Independent Generation.* In harmony with the fundamental doctrines of evolution, I assume that each species was at one time a single inter-generant; but we find that many species are now divided into two or more inter-generants, between which there is little or no inter-crossing. This state of freedom from crossing I call Se-generation. Se-generation is of two kinds, Separate Generation and Segregate Generation.

*Separate generation*, or *separation*, is the indiscriminate division of a species into groups that are prevented from freely crossing with each other.

*Segregate generation*, or *segregation*, is the inter-generation of similar forms and the prevention of inter-generation between dissimilar forms.

*Select generation*, or *selection*, is the partial or complete exclusion of certain forms from the opportunity to propagate, while others succeed in propagating. The generation of any form is *select* with reference to the non-generation of forms that fail of propagating, and *segregate* with reference to the generation of forms that propagate successfully, but separately.

*Adaptational selection* is exclusive generation that depends upon superior adaptation either to the environment or to other members of the same species.

*Natural selection* is the exclusive generation of those better fitted to the natural environment, resulting from the failure to generate of those less fitted.

*Artificial selection* is the exclusive generation of those better fitted to the rational environment.

*Reflexive selection* is the exclusive generation of those better fitted to the relations in which the members of the same species stand to each other. Sexual, social, and institutional selection are forms of reflexive selection.

*The environment* is nature lying outside of the inter-generant. The influence of the environment is the sum of the influences that fall upon

the members of an inter-generant, exclusive of their influence upon each other. The environment of an inter-generant includes members of the same species only when these members are so near that they exert an influence through competition or otherwise, while at the same time they are so far differentiated that they do not inter-cross; in other words, the members of the same species can mutally belong to the environment only when they have acquired some of the characteristics of independent species. The same environment extends as far as the activities that affect or may affect the species extend without undergoing change.

*Change in the environment* is change in the external activities affecting the species.

*Entering a new environment* is a change in the territorial distribution of the species, bringing either all or a portion of its members within the reach of new influences. This may also be called *change of environment.*

*Change in the organism*, whether producing new adaptations to the environment or not, should be carefully distinguished from both of the above-described changes.

*Change of relations to the environment* may be produced by change in the environment, or by entering a new environment, or by change in the organism.

As great confusion has been occasioned by the terms "conditions of life," and "external conditions" being used, sometimes for activities outside of the species under consideration and sometimes for those within the species (as for example the influence upon the seed produced by its position in the capsule), I have tried to avoid their use.

*Monotypic evolution* is any transformation of a species that does not destroy its unity of type.

*Polytypic evolution* or *divergent evolution* is any transformation of a species in which different types appear in different sections.

## CHAPTER I.

### THE EFFECTS OF SELECTION AND INDEPENDENT GENERATION CONTRASTED.

In as far as any theory of evolution fails of giving an explanation of divergence of character, in so far it fails of explaining the origin of species. This is the crucial test which must decide the strength or weakness of every theory that is brought forward to account for the derivation of many species from one original species. A satisfactory theory will not only point out the conditions on which divergence depends, but will show that these conditions are the natural result of causes that are already recognized by science as having influence in the organic world, or that are now shown to have such influence.

In the present chapter I shall present some reasons for believing that neither "natural selection," nor "sexual selection," nor "the

advantage of divergence of character," nor "difference of external conditions," nor all these taken together, nor any form of selection that may be hereafter discovered, is sufficient to account for divergence of character, but that another factor of equal if not superior importance must be recognized. In subsequent chapters I shall try to trace the causes on which this additional factor depends, and to indicate as far as possible the laws and relations under which they appear.

### DIVERGENT EVOLUTION NOT EXPLAINED BY NATURAL SELECTION.

Natural selection is the exclusive generation of certain forms through the failure to live and propagate, of other kinds that are less adapted to the environment.

In the case of the breeder, no selection avails anything that does not result in some degree of exclusion. In the case of natural selection, where we are not considering ineffectual intentions, the selection is measured by the exclusion. Where there is no exclusion there is no selection, and where the exclusion is great the selection is severe. Moreover it is self-evident that there can be no crossing between the best fitted that survive and propagate and the least fitted that perish without propagating. To this extent, therefore, the prevention of crossing is complete. And further, it is evident that those whose meager fitness gives them but little opportunity for propagating will have a correspondingly diminished opportunity for crossing with the best fitted; and so on through the different grades of fitness, the power to affect the next genneration through having a share in propagating will measure the power to affect the progeny of the best fitted by crossing with them. It therefore follows that the freest crossing of the fittest is with the fittest.

*Natural selection* therefore proves to be *a process in which the fittest are prevented from crossing with the less fitted through the exclusion of the less fitted*, in proportion to their lack of fitness. Through the premature death of the least fitted, and the inferior propagation of the less fitted, there arises a continual prevention of crossing between the less fitted and the better fitted; and without this separation the transforming influence of the laws of organic life would have no power to operate. As Darwin has pointed out, the results produced by this removal of the less fitted and separate propagation of the better fitted closely correspond with those produced by the breeder, who kills off the less desirable individuals of his stock before they have an opportunity to breed. The selection of the breeder avails nothing unless it leads to the determining of the kind that shall breed; and this he can not accomplish without preventing free crossing with those that he does not desire. He must use some method to secure the separate breeding of the form that he desires to propagate. We therefore find in both natural and artificial selection the same fundamental method.

In either case, the kind that is to propagate is determined by the selection, and those that are not to propagate are in some way excluded. The process may therefore be called the exclusive breeding of certain kinds; and *natural selection* may be defined as *the exclusive breeding of those better adapted to the environment.*

But if from one stock of horses we wish to develop two distinct breeds, one of which shall excel in fleetness and the other in strength for carrying or drawing burdens, the result will not be gained by simply preventing all that are inferior in strength or fleetness from breeding. By this process, which is the exclusive breeding of the desired kinds, we should obtain one breed with fair powers of strength and fleetness; but the highest results in either respect would not be gained. *Such experiments show that the exclusive breeding of other than average forms causes monotypic evolution, and that to secure divergent or polytypic evolution some other principle must be introduced.*

In the case of natural selection, the separation it introduces is between the living and the dead, between the successful and the unsuccessful. In other words, natural selection is the exclusion of all the forms that through lack of adaptation to the environment fail of leaving progeny, and therefore in the exclusive generation of the forms that through better adaptation to the environment are better able to propagate. *Variation with the natural selection of other than average forms may therefore account for the transformation of an ancient species into a series of successive species*, the last of which may now exist in full force; *but without the aid of se-generation it will by no means account for the divergent evolution of any one of these species into a family of coexisting species.*

As I have just shown, natural selection is the exclusive generation of those better fitted to the environment; and it tends to the modification of species simply through the generation of the better fitted forms, while they are prevented from crossing with the less fitted, which fail of propagating through their lack of fitness. Now, from the very nature of this process, which results from the success and failure of individuals in appropriating the resources of the environment, it follows that it can not be the cause of separation between the successful competitors, and therefore any divergence of character that arises between the different groups of the successful can not be attributed to natural selection. Natural selection explains the prevention of crossing between the fitted and the unfitted, and shows how the successive generations of a species may gradually depart from the original type, becoming in time a different species; but *it can not explain the divergences that arise between those that have, by the fact of successful propagation, proved their fitness.* It depends on superiority of adaptation to the environment, and tends to produce increasing adaptation; but *divergent kinds of adaptation are not necessary conditions for it, and it can not be the cause of increasing divergence between the incipient kinds that otherwise arise.*

### DIVERGENT EVOLUTION NOT EXPLAINED BY "THE ADVANTAGE OF DIVERGENCE OF CHARACTER."

Two sections of the fourth chapter of the "Origin of species" are given to the discussion of the "principle of benefit being derived from divergence of character," which it is maintained "will generally lead to the most different or divergent variations being preserved and accumulated by natural selection." Now, it can not be doubted that ability to appropriate unused resources would be an advantage to any members of a community pressed for food; but I do not see how the divergence that would enable them to appropriate, for example, a new kind of food can be accumulated while free crossing continues; and natural selection can not prevent the free crossing of competitors who leave progeny.

Having found that the evolution of the fitted is secured through the prevention of crossing between the better fitted and the less fitted, can we believe that the evolution of a special race, regularly transmitting a special kind of fitness, can be realized without any prevention of crossing with other races that have no power to transmit that special kind of fitness? Can we suppose that any advantage, derived from new powers that prevent severe competition with kindred, can be permanently transmitted through succeeding generations to one small section of the species while there is free crossing equally distributed between all the families of the species? Is it not apparent that the terms of this supposition are inconsistent with the fundamental laws of heredity? Does not inheritance follow the lines of consanguinity, and when consanguinity is widely diffused, can inheritance be closely limited? When there is free crossing between the families of one species, will not any peculiarity that appears in one family either be neutralized by crosses with families possessing the opposite quality, or being preserved by natural selection, while the opposite quality is gradually excluded, will not the new quality gradually extend to all the branches of the species, so that, in this way or in that, increasing divergence of form will be prevented?

If the advantage of freedom from competition in any given variation depends on the possession, in some degree, of new adaptations to unappropriated resources, there must be some cause that favors the breeding together of those thus specially endowed, and interferes in some degree with their crossing with other variations, or, failing of this, the special advantage will in succeeding generations be lost. As some degree of independent generation is necessary for the continuance of the advantage, it is evident that the same condition is necessary for the accumulation through natural selection of the powers on which the advantage depends. *The advantage of divergence of character can not be retained by those that fail to retain the divergent character; and divergent character can not be retained by those that are constantly crossing with other kinds; and the prevention of free crossing between those that are equally successful is in no way secured by natural selection.*

## NATURAL SELECTION WITH GREAT DIFFERENCE IN EXTERNAL CONDITIONS NOT SUFFICIENT TO EXPLAIN DIVERGENT EVOLUTION.

The insufficiency of natural selection without se-generation to account for divergent evolution in an area where the external conditions are nearly uniform may be admitted by some who will claim that the case is quite otherwise when a species ranges freely over an area in which it is subjected to strongly contrasted conditions. It may be claimed that diversity of natural selection resulting from a great difference in external nature is sufficient to account for divergent evolution without any se-generation.

In the discussion of this subject important light can be gained by referring to the experience of the breeder. This experience, in as far as it relates to the subject of separation in the production of divergent breeds, may be arranged under three heads: First, diversity of selection without separation; second, separation without diversity of selection; third, separation more or less complete with diversity of selection.

As the full discussion of these points is impossible here, and as there is probably but little difference of opinion in regard to what the results would be, I shall content myself with a simple statement of what I believe the experience of breeders shows. Difference in the standards of selection without separation can avail nothing in creating divergence of types; while separation without difference in the standards of selection will avail something, though food and external conditions are kept the same; but to secure the greatest divergence in a given time, there must be both diversity of selection and complete separation. In the case of separation without diversity of selection, there is room for difference of opinion; for the examples that some would claim as proving that there is often divergence without diversity of selection and without difference in external conditions may be attributed by others to unconscious selection. It is granted by everyone that no skill in selecting the animals that possess the desired qualities will have any effect in establishing a new breed unless the selected animals are prevented from breeding with others that are deficient in the desired qualities. We further find that while separation is an absolutely essential condition for this divergence, diversity of selection is not so essential. This is illustrated in the case of the slightly different types that are presented by the wild cattle found in the different parks of England,* a phenomenon which can hardly be attributed to any diversity in the environment.

In artificial breeding universal experience teaches that variation and selection, without separation, do not produce divergence of races. The separate breeding of different classes of variation is a necessary condition for the accumulation of divergent variation; and wherever the separate breeding of different classes of variation is secured there diver-

* See Darwin's "Variation under Domestication," chapter xv, second page.

gence of character is the result. In other words, segregate breeding is necessary to divergent evolution in gamo-genetic animals.* Moreover, we have every reason to believe that the same law holds good throughout the whole organic world. The generating together of similars, with the exclusion or separation of dissimilars, is the central necessity in all evolution by descent, whether monotypic or polytypic and *whatever causes the separate generation of different classes of variation will be the cause of divergent evolution.* That is, wherever this condition is added to the permanent laws of organic life, there divergence will follow. As we have already seen, natural selection or the survival of the fittest necessarily separates between the survivors and the nonsurvivors, between the best fitted and the least fitted, and is, therefore, the cause of monotypic transformation; but it can not be the cause of separation between the different families of those that survive, and, therefore, can not be the cause of divergence of character between these families. But we find that divergence of character often arises between the branches of one stock, and in many cases this divergence increases till well-marked varieties are established. If therefore the general principle we have just stated is true, there must be certain causes producing the independent generation of these forms; and, if we can discover these causes and trace them to general principles, they will, in connection with the laws of variation and selection, explain divergent evolution, that is, the transformation of one form into many forms, of one species into many species. As community of evolution arises where there is community of breeding between those that, through superior fitness, have opportunity to propagate, so I believe it will be found that divergent evolution arises where there is separate breeding of the different classes of the successful. In other words, exclusive breeding of other than average forms causes monotypic evolution, and segregate breeding causes divergent or polytypic evolution.

The facts of geographical distribution seem to me to justify the following statements:

(1) A species exposed to different conditions in the different parts of the area over which it is distributed is not represented by divergent forms when free inter-breeding exists between the inhabitants of the different districts. In other words, diversity of natural selection without separation does not produce divergent evolution.

(2) We find many cases in which areas, corresponding in the character of the environment, but separated from each other by important barriers, are the homes of divergent forms of the same or allied species.

(3) In cases where the separation has been long continued, and the external conditions are the most diverse in points that involve diver-

* In a subsequent paper I shall show how it is that separate breeding, long continued, inevitably ends in segregate breeding. In this chapter I confine my attention more especially to separate breeding when combined with diversity of selection in the different sections, for it is evident that this will produce segregate breeding.

sity of adaptation, there we find the most decided divergences in the organic forms. That is, where separation and divergent selection have long acted, the results are found to be the greatest. The first and third of these propositions will probably be disputed by few, if by any. The proof of the second is found wherever a set of closely allied organisms is so distributed over a territory that each species and variety occupies its own narrow district, within which it is shut by barriers that restrain its distribution, while each species of the environing types is distributed over the whole territory. The distribution of terrestrial mollusks on the Sandwich Islands presents a great body of facts of this kind.

### SELECTION OF EVERY KIND INSUFFICIENT TO ACCOUNT FOR DIVERGENT EVOLUTION.

Though I have no reason to doubt the importance of sexual selection in promoting the transformation of many species, I think I can show that unless combined with some separative or segregative influence that prevents free intercrossing, it can avail nothing in producing a diversity of races from one stock. In the nature of its action sexual selection is simply exclusive. It is the exclusive breeding of those better fitted to the sexual instincts of the species, resulting from the failure to breed of the less fitted. It therefore indicates a method of separation between the better fitted and the less fitted; but it gives no explanation of separation between those that are equally successful in propagating.

I maintain that in a great number of animal species there are sexual and social instincts that prevent the free crossing of clearly marked races; but as these segregative instincts are rarely the cause of failure to propagate, and since when they are the cause of failure the failure is as likely to fall on one kind as on another, I conclude that the segregate breeding resulting from these instincts can not be classed as either sexual or social selection. Reflexive selection in all its forms is, like natural selection, the result of success and failure in vital processes through which the successful propagate without crossing with the unsuccessful; but it in no way secures the breeding in separate groups of those that are successful in propagating. The exclusion of certain competitors from breeding is a very different process from the separation of the successful competitors into different groups that are prevented from inter-crossing, and whose competition even is often limited to the members of the same group. Sexual selection, like other forms of reflexive selection, can extend only as far as members of the same species act on each other. If the individuals of the two groups have through difference in their tastes ceased to compete with each other in seeking mates, they are already subject to different and divergent forms of sexual selection; and is there any reason to attribute this

difference in their tastes to the fact that, when there was but one group and the tastes of all were conformed to a single standard, some of the competitors failed of propagating, through being crowded aside by those more successful? *If the failure of the unsuccessful can not be the cause of separation between the different kinds of the successful, then selection, whether natural or reflexive, or of any other kind, can not be the cause of divergent evolution, except as co-operating with some cause of independent generation.*

The failure of sexual selection, without separation or segregation, to account for divergent evolution, will perhaps be made clearer to some minds by considering some of the particular conditions under which it occurs. Suppose for instance that in some species of humming bird there occurs a slight variation in the form or color of the tail feathers of the male that adds to the beauty of the individuals possessing the new character and rendering them more attractive to the females. We can see that they might have an advantage over their rivals in leaving progeny, and that the variety might in that way gradually gain the ascendency, and the beauty of the markings become more and more completely defined; but under such conditions what could prevent the whole species from being gradually transformed? Unless there was some separative or segregative principle that prevented the new variety from crossing with the others, the species would remain but one, though changed in some of its characters. We should have transformation without divergence.

The same must be true of institutional selection. It may be the cause of transformation; but it can not be the cause of divergent evolution, unless there are added to it other causes that produce divergence in the character of the forms selected, and the separate breeding of the different groups of forms thus selected. A single illustration will set in a clear light the limitation in the influence of institutional as well as all other selection. In primitive communities the deaf are but little cared for, and owing to the great disadvantage of their position their opportunities for gaining subsistence, and therefore for rearing families, are greatly diminished; this is natural selection. Again, those who are at so great a disadvantage in communicating with their companions will be also at a disadvantage in finding consorts; this we may call social selection. Again, a community might either by law or by strict custom prevent the marriage of the deaf; this would be institutional selection. Any one of these forms of selection might be pressed so far as to be the means of increasing the average power of hearing in the community in succeeding generations; but it could never be the cause of two divergent races, one with good powers of hearing and the other with an increasing liability to deafness. To secure such divergence it is necessary that segregative influences should be introduced, such as have been most amply furnished by the modern system of education for the deaf. Under these influences those endowed with hear-

ing and those without hearing have been separated into two communities, the members of each having but little opportunity for acquaintance beyond the limits of that community, each community having separate schools, separate newspapers, and to some extent a separate language. As the result of this segregation marriages between the two classes have been greatly diminished; and little by little two races are arising, the hearing race and the deaf race.*

### REASONS OF A GENERAL CHARACTER FOR CONSIDERING SELECTION WITHOUT INDEPENDENT GENERATION AN UNSATISFACTORY EXPLANATION OF DIVERGENT EVOLUTION.

1. The divergence is often confined to characters which seem to have no possible relations of adaptation either to the environment or to other members of the species, and, therefore, to be independent of both natural and reflexive selection.
2. Divergence relating to adaptive characters successfully propagated involves different kinds rather than different degrees of adaptation and advantage; and, as adaptational selection depends on the difference of degrees of advantage, it can not account for the divergence of forms possessing equal degrees of advantage.
3. In the very nature of its action we see that adaptational selection unaccompanied by independent generation must produce essentially monotypic transformation.
4. In artificial breeding, independent generation is found to be an essential condition for the production of divergent races; and there is no reason to doubt that the same law holds good in the divergence of natural forms.
5. The general fact that species possessing high powers and large opportunities for migration occupy large areas, while those possessing low powers and small opportunities for migration divide the same area, or an area no larger, between many representative species, shows that independent generation is an important element in their divergence.

## CHAPTER II.

### CUMULATIVE DIVERGENCE THROUGH CUMULATIVE SEGREGATION

Local separation in dissimilar environments is the only cause of segregation that has been clearly pointed out by Darwin. I shall however endeavor to show that there are other causes producing segregation, and that, without any change of environment or change in the environment, they may produce all the phenomena of divergent

* See paper by Alexander Graham Bell, read before the National Academy of Sciences, November 13, 1883, upon the "Formation of a Deaf Variety of the Human Race:" also a review of the same in *The Popular Science Monthly*, vol. XXVII, p. 15, entitled "Can Man be Modified by Selection?"

evolution. Any cause that, out of two or more kinds of successful variations, brings together one kind in such a way as to facilitate their breeding together, or to hinder their breeding with those of other kinds, is, according to my definition, a cause of segregate breeding; and the experience of breeders shows that wherever such causes operate divergent evolution is the result, and that the divergence accumulates when the process is continued through many generations. From their experiments we learn that any form of segregate breeding persistently continued will result in divergent evolution. As any form of natural selection in which other than typical forms have the advantage will result in monotypic evolution, so any form of segregate generation will produce polytypic evolution. I call this the law of *cumulative divergence through cumulative segregation.* It is a generalization established by the widest experience of mankind in the cultivation of plants and the breeding of animals; and any assumption that is not in accord with it may be wisely called in question.

I therefore judge that the advantage or disadvantage of their divergence, to individuals diverging from the typical form of a species, can not be the factor that determines whether the divergence shall be accumulated.

A divergent member of any inter-generating group can not long perpetuate its kind, if the divergence is any disadvantage; for the superior propagation of the more successful kinds will soon overpower the influence of the less successful; and the result will be monotypic evolution. The case is, however, very different with variations that are wholly or partially separated from each other and from the type by their divergent adaptation to different kinds of resources, or by any other cause. The perpetuation of such variations depends not upon any advantage they possess above the type from which they diverge, but upon ability to appropriate from the environment sufficient simply to maintain existence, and the result is polytypic evolution. In other words, of the freely crossing forms of any species it is only those that are most successful that are perpetuated; while *of forms that are neither competing nor crossing, every kind is perpetuated that is not fatally deficient in its adaptations.* It follows that a form that under present conditions maintains only a precarious existence, may, if kept from crossing, maintain its characteristics unimpaired for many generations, and at last, through changes in the environment, enter upon a period of great prosperity. Such would be the case with a form depending upon resources at first scarce, and afterwards very abundant.

Again, the individuals of a species that are brought together in their attempts to appropriate some new kind of resource, and are thus led to breed with each other, and not with the rest of the species, become a new inter-generating group in which a new and divergent form of natural selection is established, depending on divergent adaptations in the organism, without any change in the environment. The gradual

process of gaining full adaptation to the new resources may extend over many generations, and during this long period the divergent form may be at a great disadvantage as compared with the typical form; but after this long process of divergence is completed, and full command of the new resource is gained, the new race may enter upon a period of great prosperity. In such a case, the period of most rapidly accumulating divergence is a period when the incipient race is suffering the heaviest disadvantage. The transformation from a wild to a domestic state affords a complete parallel to this process. In the initial and earlier stages, the divergent branch that is being domesticated is in constant danger of extermination; and it is only when a good degree of adaptation to the new conditions has been gained that it can be said to be as prosperous as the wild stock from which it was derived. Darwin has not explained how disadvantageous sexual instincts can be formed; but, assuming that there are such instincts, he has shown that they would modify the species in a way that is disadvantageous. He believes the progenitors of man were deprived of their hairy coat by sexual selection that was, in its earlier stages, disadvantageous.

It is therefore evident that the simple fact of divergence in any case is not a sufficient ground for assuming that the divergent form has an advantage over the type from which it diverges. We may however be sure that there is some cause or combination of causes that facilitates the intergenerating of those similarly endowed, and hinders their crossing with other kinds; and if we can discover the cause of this segregate generation we shall have an explanation of one part of the process by which the forms thus endowed are becoming a distinct race.

## SEPARATION AND SEGREGATION WITH THE PRINCIPLE OF INTENSION.

It will contribute to clearness in our discussion if we can gain definite conceptions of the conditions that are necessarily involved in separate and segregate breeding.

Separate generation, which for convenience I call separation, implies:

First. The indiscriminate separation of the members of a species into different sections that are prevented from freely crossing with each other.

Second. The aggregation of the members of one section; that is, their being brought into conditions of time and place that allow of their freely crossing.

Third. The integration of the members of each section into one intergenerating group, through the operation of functional adaptations by which the members of each section freely cross with each other. This analysis of the process shows that it may depend upon a great variety of causes, working together in a very complex way. We shall hereafter find that the causes of separation may operate in such a way that no aggregation or propagation takes place among the members that are separated from the old stock; but in such cases there is no

separate generation, and therefore no separation in the sense in which I use the word.

Segregate generation also consists of separation, aggregation, and integration; but it differs from separate generation in that in the latter the separation is indiscriminate, while in the former there is a more or less pronounced bringing together of those that are similarly endowed, with separation of those that are dissimilar. Segregate generation is therefore the separation of dissimilars, with the aggregation and integration of similars. As we have already seen, segregate breeding may be produced by separate breeding, accompanied by diversity of natural selection in the different sections. It is almost evident that any other cause that develops in one or more of the separate sections of the species characters that are not found in the other sections will produce segregate breeding. Such cases are diversity of selection of other forms than natural selection, diversity in the inherited effects of use and disuse (unless physiologists have been mistaken in supposing that there are any such effects), and diversity in the inherited characters derived from the direct effects of the environment (unless, again, Weismann is right and the general belief wrong). Segregate breeding may moreover be produced directly by the very way in which the separation of the different sections is secured. One of the best examples of this kind of segregation is seen in what I call industrial segregation, where the members of a species are distributed according to their endowments, those of similar endowments being brought together. In such cases, segregation is introduced as soon as the separation, without depending on the subsequent action of the environment, or on diverse forms of use, or of selection; though there can be no doubt that, in the great majority of cases, diversity of use and diversity of selection of some kind will in time come in to intensify the result.

There is another invariable sequence which it is necessary we should keep in mind if we would understand the relation in which these two principles stand to each other. I refer to the certainty that all prolonged separate breeding will be transformed into segregate breeding. In other words, indiscriminate separation, in which there is no apparent difference in the different groups, is in time found to be a separation in which there is a decided difference in the different groups. Whenever a sufficient number of the same species to insure propagation are brought together in an isolated position, separate generation is the result; and, if this separate generation is long-continued, we have reason to believe it always passes into segregate generation with divergent evolution. The fundamental cause for this seems to lie in the fact that no two portions of a species possess exactly the same average character, and that the initial differences are for ever reacting on the environment and on each other in such a way as to insure increasing divergence in each successive generation as long as the individuals of the two groups are kept from intergenerating. In my paper on *Diver-*

*sity of Evolution under one Set of External Conditions*, I spoke of this principle of divergence as "separation with variation;" but in order to distinguish the antecedent condition, which is separation, from the result, which is something more than variation, I now call the certainty that some form of divergent transformation will arise when inter-generation is prevented the principle of *intension*; and segregation produced by independent transformation I call intensive segregation.

As separate and segregate generation are so closely related, I have, in order to avoid a multiplication of terms, classified the two principles together under the general term segregation. In my discussion of the causes of segregation I shall however endeavor to determine concerning each class of causes whether they are primarily separative or segregative.

A full discussion of the causes of segregation would require that under each combination of causes to which we give a distinctive name we should show:

(1) How the independent generation is produced.

(2) How the difference of character in the different sections is produced.

(3) How the aggregation in place bringing together the members of each section is produced.

(4) How the correspondence in times and seasons necessary for inter-generation is secured within each section.

(5) How the correspondence of community and of sexual and social instincts necessary for intergeneration is secured within each section.

(6) How the correspondence in structure, in dimensions, and in the mutual potentiality of the sexual elements necessary for intergeneration is secured within each section.

It will however be observed, that with the exception of the two first, these questions relate to the necessary conditions that must always exist in the case of every inter-generating group; and as it is evident that inter-generation in some degree must be the normal condition in every sexual, that is, in every gamo-genetic species, we may here assume that all the conditions necessary to inter-generation exist, except so far as they have been disturbed by causes producing segeneration. In tracing the causes of segregation it will therefore be sufficient if in each class of cases we give the cause of se-generation, showing why the same cause does not prevent all inter-generation, and explain the difference of character in the different sections produced by the se-generation. In full accord with the implications of the theory of evolution, we proceed on the assumption that inter-generation was the original condition of every species, and that the inter-generation of those that are brought together under favorable circumstances may be taken for granted, unless there is some special cause that prevents. All that is necessary to produce separation is the failure of any one of the many conditions on which free crossing depends, in such a way and to such

a degree that the species falls into two or more sections, between which crossing is interrupted, without its being interrupted within the bounds of each section. And all that is necessary to produce segregation is that to separation should be added some cause that secures difference of character in the different sections. And as separation long continued inevitably ends in segregation through the development of difference of character in the different sections, we need not in our classification set them wholly apart, though for the sake of clearly recognizing the difference it will be well to note in each class of causes whether the primary effect is separation or segregation.

## CUMULATIVE SEGREGATION AND THE CLASSIFICATION OF ITS DIFFERENT FORMS.

The fundamental law to which I would call attention may be expressed in the following formula: Cumulative segregation produces accumulated divergence and accumulated divergence produces permanent segregation, and the segregate subdivision of those permanently segregated produces the divisions and subdivisions of organic phyla. If then we can discover the causes of segregation, we shall understand the causes of a wide range of phenomena, for this is the fundamental principle in the formation of varieties, species, genera, families, orders, and all greater divergences that have been produced in the descendants of common ancestry.

In treating of the causes of segregation I have found it convenient to make two distinct classifications. In the one the fundamental distinction is between segregation produced by the purpose of man, which I call rational segregation in its two forms, artificial segregation, institutional segregation, and that produced by nature outside of man, which I call responsive segregation; while any of these forms of segregation may be intensified by independent transformation through the principles of diversity of selection, diversity of use, or diversity of direct effects of the environment; and the combined action of segregation with these and other principles of transformation I call intensive segregation.

In the other classification the fundamental distinction is between segregation arising from the relations in which the organism stands to the environment, which I call environal segregation, and segregation arising from the relations in which the members of the same species stand to each other, which I call reflexive segregation; while any form of segregation belonging to either of these classes may be enhanced by one or more of the forms of intension, and thus present what I call insive segregation.

## THE EFFECTS OF SEGREGATION.

The effects of segregation can be studied to advantage in the vast experience that has been accumulated in the domestication of plants and animals.

Artificial segregation is caused by the relations in which the organism stands to the rational environment, that is, to the purposes of man. In other words, artificial segregation is the rational form of environal segregation. Though the bearing of segregation on the evolution of species in a state of nature has been for the most part overlooked, its effects have been quite familiar to the breeder of domestic races.

As a convenient method of illustration, let us consider the different results that will be gained according as we subject the same ten pairs of wild rock pigeons to one or the other of the following methods of treatment:

In the first experiment let the treatment be as follows: Let ten aviaries be prepared, and in each aviary put one male with the female that most nearly resembles it. When the young of each aviary arrive at maturity, let them be inspected, and if any individual resembles the inmates of one of the other aviaries more than the inmates of the aviary in which it was produced, let it be placed with those it most closely resembles. If any unusual variation arises, let it be placed in a new aviary, and let the one of the other sex that most closely resembles it in that respect be placed with it. When the crowding in any aviary becomes injurious to the health of the birds let the numbers be indiscriminately reduced. Let this process be continued many generations, the inmates in all the aviaries being fed on the same food, and in every respect treated alike, and what will be the result?

No experienced breeder will hesitate in assuring us that under such treatment a multitude of varieties will be formed, many of which will be very widely divergent from the original wild stock. In other words, *cumulative segregation will produce accumulated divergence, though there is no selection in the sense in which natural selection is selection.*

Again, let us take the same ten pairs, and putting them into one large aviary, let them breed freely together without any segregative influence coming in to affect the result, and who does not know that the type would remain essentially one, though a considerable range of individual variation might arise. That is, *without segregation no divergence of type will arise.*

### THE NATURAL LAW OF CUMULATIVE SEGREGATION.

I shall now show that there is in nature a law of cumulative segregation. There are large classes of activities in the organism and in the environment that conspire to produce segregate breeding; and to produce it in such a way that in a vast multitude of cases it becomes a permanent fact, which no cause that we are acquainted with can ever obliterate. Moreover, when one form of segregation has become fully established, we find that the different branches are liable to be again subjected to segregative influences, by which each branch is subdivided, and in time differentiated into divergent forms that are not liable to inter-cross in a state of nature.

Now, as we have just pointed out, we know from the fundamental laws of the organic world, that cumulative segregation of this kind must produce cumulative divergence of types.

The segregation that results from the natural causes enumerated in this paper is cumulative in two respects. In the first place, every new form of segregation that now appears depends on, and is superimposed upon, forms of segregation that have been previously induced; for when negative segregation arises, and the varieties of a species become less and less fertile with each other, the complete infertility that has existed between them and some other species does not disappear, nor does the positive segregation (that is, the prevention of the consorting of the species characterized by this mutual incapacity) cease. The means by which the males and females of one species find each other are not abrogated when the species falls into segregated varieties. In the second place, whenever segregation is directly produced by some quality of the organism, variations that possess the endowment in a superior degree will have a larger share in producing the segregated forms of the next generation, and accordingly the segregative endowment of the next generation will be greater than that of the present generation; and so with each successive generation the segregation will become increasingly complete.

The principle of cumulative segregation, first in its independent action, and still further when combined with the different principles by which the divergence of the segregated branches is intensified, gives a formal explanation of the ever-expanding diversities of the organic world. It shows how varieties arise and pass into species, how species pass into genera, genera into families, families into orders, and orders into classes and the higher divisions, as far as evolution by descent extends. It brings to light the dependence of this whole process on the influences that produce segregation; and shows how these influences, added to variation, heredity, and the other acknowledged powers residing in organisms, must produce the phenomena of divergent evolution.

## COMPETITIVE DISRUPTION.

Before entering upon the discussion of the direct causes of cumulative segregation, let us briefly consider a law resulting from the competition of kindred with each other, which brings to light the fact that such competition is one of the most important factors in preparing the way for, and in giving intensity to, the activities that lead to segregation and divergent evolution. It is manifest that competition for identical resources and geographical segregation are conditions which can not exist at the same time between the same members of any species; but it is also manifest that when there are no natural barriers separating the different districts of an area, part of which is occupied by a species, pressure for food through a great increase in the population

will tend to distribute the species over the whole area; and if the available resources in the different districts are considerably diverse, the overflow of population from the crowded district will be subjected to a necessary change of habits; and thus, through competition, there will be the disruption of old relations to the environment, and the bringing in of conditions that give the highest efficiency and the fullest opportunity to all the activities that produce segregation. In the case of animals, no condition can tend more strongly to produce migration than scarcity of food in the old habitat; and in the case of both plants and animals, a great increase in the numbers that are exposed to the winds, currents, and other transporting influences of the environment increases the probability that individuals will be carried to new districts where circumstances will allow of their multiplying, and where they will, at the same time, be prevented from crossing with the original stock. In many cases the segregation thus brought about will be in districts where the environment is the same, and in other cases the pressure for food or other resources will lead portions of the species to take up new habits in the effort to appropriate resources not previously used; and through these new habits they will often be segregated from those maintaining the original habits. I shall hereafter show that in both these cases there is a tendency to divergent evolution.

I at one time thought of describing this principle as a form of segregation, calling it *dominational segregation;* but fuller reflection convinces me that the domination of the strong over the weak is not a form of segregation, but rather a cause that prepares the way for segregation, by forcing portions of the community out of their inherited relations to the environment.

## CHAPTER III.

### DESCRIPTION AND CLASSIFICATION OF THE CAUSES OF CUMULATIVE SEGREGATION.*

#### A. ENVIRONAL SEGREGATION.

Environal segregation is segregation arising from the relations in which the organism stands to the environment.

It includes four classes, which I call industrial, chronal, spatial, and artificial segregation.†

#### (*a*) *Industrial segregation.*

is segregation arising from the activities by which the organism protects itself against adverse influences in the environment, or by which it finds and appropriates special resources in the environment.

* In the following chapters numerals are attached to what I consider separate causes of segregation independent of human purpose.

† Francis Galton has suggested another class, which might appropriately be called fertilizational segregation.

The different forms of industrial segregation are sustentational, protectional, and nidificational segregation.

For the production of industrial segregation it is necessary that there should be, in the same environment, a diversity of fully and of approximately available resources more or less separated from each other, and in the organism some diversity of adaptation to these resources, accompanied by powers of search and of discrimination, by which it is able to find the resources for which it is best fitted and to adhere to the same when found.

The relation in which these causes stand to each other and through which they produce segregation may be described as separation according to endowment—produced by endeavor according to endowment.

It is evident that if initial variation presents in any case a diversity of adaptations to surrounding resources that can not be followed with out separating those differently endowed, we shall have, in the very nature of such variation, a cause of segregation and of divergent evolution. Some slight variation in the digestive powers of a few individuals makes it possible for them to live exclusively on some abundant form of food, which the species has heretofore only occasionally tasted. In the pressure for food that arises in a crowed community these take up their permanent abode where the new form of food is most accessible, and thus separate themselves from the original form of the species. These similarly endowed forms will therefore breed together, and the offspring will, according to the law of diversity through segregation, be still better adapted to the new form of food. And this increasing adaptation, with increasing divergence, might continue for many generations, though every individual should come to maturity and propagate; that is, though there were no enhancing of the effect through diversity of selection, or indeed through any other cause producing intensive segregation. And when different forms of intention do arise they may be entirely independent of change in the environment, the only change being in the forms or functions of the organism.

In choosing a name for this form of segregation I first thought of calling it physiological or functional segregation; but such a name is, on closer examination, found to imply both too much and too little; for, on the one hand there is probably no form of segregation that is not in some way or in some degree due to physiological or functional causes, and on the other hand this special form of segregation is as dependent on psychological causes which guide the organism in finding and in adhering to the situation for which it is best fitted, as it is on the initial divergence of the more strictly physiological adaptations by which it is able to appropriate and assimilate the peculiar form of resource. In the case of freely-moving animals the psychological guidance is an essential factor in the success of the individual; while in the case of plants and low types of animal life, the suitable situation is reached by a wide distribution of a vast number of seeds, spores, or germs, and

the same situation is maintained by a loss of migrational power as soon as the germs begin to develop. In these lower organisms it is evident that the success of the individual must depend on its physiological rather than its psychological adaptations; and if an initial divergence of adaptations results in a slight difference in the kinds that succeed in germinating in contrasted situations, the difference is directly due to a diversity in the forms of natural selection affecting the seed, and the separation is what I hereafter describe as local separation, passing into local segregation. We therefore see that what I here call industrial segregation depends on psychological powers acting in aid of divergent physiological adaptations to the environment, or in aid of adaptations that are put to different uses.

Observation shows that there is a multitude of cases in which endeavor according to endowment brings together those similarly endowed and causes them to breed together; and when the species is thus divided into two or more groups somewhat differently endowed, there will certainly be an increased divergence in the offspring of the parents thus segregated; and so on in each successive generation, as long as the individuals find their places according to their endowments, and thus propagate with those similarly endowed, there will be accumulated divergence in the next generation. Indeed it is evident that endeavor, according to endowment, may produce under one environment what natural selection produces when aided by local separation in different environments. As it produces the separate breeding of a divergent form without involving the destruction of contrasted forms, it is often the direct cause of divergent transformations; while natural selection, which results in the separate breeding of the fitted through the failure of the unfitted, can never be the cause of divergence unless there are concurrent causes that produce both divergent forms of natural selection and the separate breeding of the different kinds of variations thus selected.

*Suetudinal intension.*—Another law is usually believed to be connected with endeavor which, if it exists, must conspire to enhance its tendency to produce divergent evolution. I refer to the influence which the habitual endeavor of the parents has on the inherited powers of the offspring. We may call it the law of endowment of offspring according to the exercise or endeavor of parents, or, more briefly, suetudinal intension. The inherited effects of use and disuse have been fully recognized by Darwin, Spencer, Cope, Murphy, and others, and need not here be discussed. The one point to which I wish to call attention is, that in order that diversity of use should produce divergent evolution, it is necessary that free crossing should be prevented between the different sections of the species in which the diversity of use is found. Now this condition of separate breeding is often secured by industrial segregation. In other words, the law of endeavor, according to endowment, often secures separation according to endowment, and this gives an opportunity

for the inheritable effects of diversity of endeavor to be accumulated in successive generations, and in this way both laws conspire to produce divergent evolution.

In the relation of these two factors we have a striking example of the peculiar interdependence of vital phenomena. Diversity of endowment is the cause of diversity of endeavor and of segregate breeding, and diversity of endeavor with segregate breeding is the cause of increased diversity of endowment. It is very similar to the relation between power and exercise in the individual. Without power there can be no exercise, and without exercise there can be no continuance or growth of power.

We therefore see that the effects of industrial segregation are specially liable to be enhanced by that form of intensive segregation which I have suggested should be called suetudinal intension.

Simple and familiar as the principles of industrial segregation and suetudinal intention may seem, their consistent application to the theory of evolution will throw new light on a wide range of problems. This law of divergent evolution through industrial segregation rests on facts that are so fully acknowledged by all parties, that it seems to be a superfluous work to gather evidence on the subject. It may however be profitable to consider briefly whether the cases are frequent in which different habits of feeding, of defense, or of nest-building become the cause of separate breeding by which the same habits are maintained in one line of descent without serious interruption for many generations. It is important to remember, (1) that the separate breeding will arise with equal certainty whether the diversity in the habits has been initiated by original diversity in the instincts and adaptations of the different variations, or by the crowding of population inducing special efforts to find new resources, and leading to diversity of endeavor; and (2) that in either case the result is what is here called industrial segregation. In the first case the process is directly segregative, while in the second case it is primarily separative, but (according to the principle discussed in the second section of last chapter) inevitably passes into segregate breeding. Suetudinal intention, or divergent evolution through diversity of use, will operate as surely in the one case as in the other.

1. *Sustentational segregation* arises from the use of different methods of obtaining sustentation by members of the same species.

There can be no doubt that of the innumerable cases where phytophagic varieties (as they are sometimes called) of insects exist, a considerable proportion would be found on investigation to be permanent varieties producing offspring that are better adapted to the use of the special form of food consumed by the parents than are the offspring of other varieties; and it is evident that if the peculiar habits of each variety had no tendency to produce segregative breeding this result would not be reached; for each variety would be promiscuously min-

gled with every other, and, though the tendency to variation might be greatly increased, the regular production of any one variety of young would be prevented.

A large mass of facts could be easily gathered illustrative of sustentational segregation; but as the principle will probably be denied by no one, we should pass on without further expansion of this part of the subject.

2. *Protectional segregation* is segregation from the use of different methods of protection against adverse influences in the environment.

When a new enemy enters the field occupied by any species different methods of escape or defense are often open to the members of the one species, and the use of these different methods must sometimes result in the segregation of the members according to the methods adopted. Some may hide in thickets or holes, while others preserve themselves by flight. Supposing the species to be an edible butterfly occupying the open fields, and the new enemy to be an insectivorous bird also keeping to the open country, certain members might escape by taking to the woodlands, while others might remain in their old haunt, gaining through protectional selection more and more likeness to some inedible species.

3. *Nidificational segregation.*—Let us now consider the effects of divergent habits in regard to nest-building. It is well known to American ornithologists that the cliff swallow of the eastern portions of the United States has for the most part ceased to build nests in the cliffs that were the original haunts of the species, and has availed itself of the protection from the weather offered by the eaves of civilized houses; and that with this change in nest-building has come a change in some of its other habits. Now there is reason to believe that if the number of houses had been limited to a hundredth part of those now existing, and if that limited number had been very slowly supplied, this gradual change in some of the elements of the environment would have resulted in divergent forms of adaptation to the environment in two sections of the same species. One section would have retained the old habit of building in the cliffs, with all the old adaptations to the circumstances that depend on that habit; while another section of the species would have availed itself of the new opportunities for shelter under the eaves of houses, and would have changed their inherited adaptations to meet the new habits of nest-building and of feeding. It is also evident that the prevention of free inter-breeding between the different sections caused by the diversity of habits would have been an essential factor in the divergence of character in the sections.

It simply remains to consider whether the industrial habit that separates an individual from the mass of the species will necessarily leave it alone, without any chance of finding a consort that may join in producing a new intergenerant. The answer is that there is no such necessity. Though it may sometimes happen that an individual may

be separated from all companions by its industrial habit, it is usually found that those that at one time and one place adopt the habit are usually sufficient to keep up the new strain, if they succeed in securing the needed sustenance.

(*b*) *Chronal segregation.*

is segregation arising from the relations in which the organism stands to times and seasons.

I distinguish two forms—cyclical and seasonal segregation.

4. *Cyclical segregation* is segregation arising from the fact that the life cycles of the different sections of the species do not mature in the same years.

A fine illustration of this form of segregation is found in the case of *Cicada septemdecim*, whose metropolis is in Virginia, Maryland, and Delaware, though many outlying broods are found in other regions east of the Mississippi River. The typical form has a life-cycle of seventeen years, but there is a special race (*Cicada tredecim*, Riley) that is separated from the typical form, both locally and chronally. As the life-cycle of this race is thirteen instead of seventeen years, even if occupying the same districts and breeding at exactly the same season, inter-breeding could occur between the two forms only once in two hundred and twenty-one years, or once in thirteen generations of the longer lived race, and once in seventeen generations of the shorter lived race. During the year 1885 the two races appeared simultaneously. The opportunity for testing whether they would freely interbreed if brought together has therefore passed not to return till the year 2106; but the distribution of the two races in different districts seems to indicate that local segregation has had an important influence in the development of the race. It is manifest, however, that if during a period of local separation, or if during the period of two hundred and twenty-one years of cyclical separation after the thirteen-year race was first formed, this race should become modified in the season of its appearing, there would after that be no mingling of race, though brought together in the same districts. This would be seasonal segregation, which we shall consider in the next section; but what is of special interest here, as an example of complete cyclical segregation, is the fact that at Fall River, Mass., there is a brood of the *septemdecim* form, due a year later than the universal time of appearing.*

In any species where the breeding of each successive generation is separated by an exact measure of time which is very rigidly regulated by the constitution of the species, cyclical segregation will follow, if through some extraordinary combination of circumstances, members

* See statement by Prof. C. V. Riley, in *Science*, vol. VI, p. 4. For particulars concerning the distribution and habits of this species, see a paper by Prof. Riley, read before the Biological Society of Washington, May 30, 1885, extracts from which are given in *Science*, vol. V, p. 518.

sufficient to propagate the species are either hastened or delayed in their development, and thus thrown out of synchronal compatibility with the rest of the species. If, after being retarded or hastened in development so that part of a cycle is lost or gained, the old constitutional time measure reasserts itself the segregation is complete.

So far as this one point relating to the time of maturing is concerned the constitutional difference is segregative, while in every other respect it will be simply separative, except as separation passes into segregation. The Fall River brood of *Cicada septemdecim* being entirely separated from all other broods of the same race by being belated a year may be modified by forms of natural selection that never arise in these other broods. And this may be the case even if a brood observing the ordinary time is always associated with it in locality.

5. *Seasonal segregation* is produced whenever the season for reproduction in any section of the species is such that it can not interbreed with other sections of the species. It needs no argument to show that if in a species of plant that regularly flowers in the spring, there arises a variety that regularly flowers in the autumn, it will be prevented from interbreeding with the typical form. The question of chief interest is, Under what circumstances are varieties of this kind likely to arise? Is a casual sport of this kind likely to transmit to subsequent generations a permanently changed constitution? If not, how is the new constitution acquired? One obvious answer is that it may arise under some special influence of the environment upon members of the species that are geographically or locally segregated from the rest of the species.

But may not the variation in the season of flowering be the cause of segregation that will directly tend to produce greater variation in that respect in the next generation, and so on till the divergence in the constitutional adaptation to season is carried to the greatest extreme that is compatible with the environment? I believe that it not only may but must have that effect; but we should remember that the average form which flowers at the height of the season will so vastly predominate over the extreme forms that the latter will be but stragglers in comparison.

In regard to the one point of the season of readiness for propagation this principle is segregative; but in other respects it is simply separative, unless through the principle of correlated variation other characters are directly connected with the constitution that determines the season. It will be observed that seasonal segregation is produced by a parallel and simultaneous change in the constitution of members in one place sufficient to propagate the species; while cyclical segregation is produced by a simultaneous acceleration or retardation in the development of members in one place sufficient to propagate the species without disturbing the regular action of the constitution under ordinary circumstances.

(*c*) *Spatial segregation*

is segregation arising from the relations in which the organism stands to space.

I distinguish two forms, viz: geographical and local segregation.

*Geographical segregation* is segregation that arises from the distribution of the species in districts separated by geographical barriers that prevent free inter-breeding. Decided differences of climate in neighboring districts and regions may be classed as geographical barriers.

*Local segregation* is segregation that arises when a species with small powers of migration and small opportunities for transportation has been in time very widely distributed over an area that is not subdivided by geographical barriers. The segregation in this case is due to the disproportion between the size of the area occupied and the powers of communication existing between the members of the species occupying the different parts of the area. Though it is often difficult to say whether a given case of segregation should be classed as geographical or local, still the distinction will be found useful, for the results will differ according as the segregation is chiefly due to barriers or to wide diffusion of the species. In geographical segregation the result is usually the development of well-defined varieties or species on opposite sides of the barriers; but in local segregation it often happens that the forms found in any given locality are connected with those in surrounding localities by individuals presenting every shade of intermediate character; and in general terms it may be said that the forms most widely separated in space are most widely divergent in character. It is of course apparent that when the divergence has reached a certain point, the differentiated forms may occupy the same districts without inter-breeding, for they will be kept apart by some, if not all, of the different forms of industrial, chronal, conjunctional, and impregnational segregation.

Three different forms of spatial segregation may be distinguished according to the causes by which they are produced, viz:

6. *Migrational segregation*, caused by powers of locomotion in the organism.

7. *Transportational segregation*, caused by activities in the environment that distribute the organism in different districts (prominent among these are currents of atmosphere and of water, and the action of migratory species upon those that can simply cling).

8. *Geological segregation*, caused by geological changes dividing the territory occupied by a species into two or more sections. For example, geological subsidence may divide the continuous area occupied by a species into several islands, separated by channels which the creatures in question can not pass.

Migration differs from transportation simply in that the former is the direct result of activities in the organism, and the latter of activities in the environment; and though the distribution of every species de-

pends on the combined action of both classes of activities, it is usually easy to determine to which class the carrying power belongs. The qualities of the thistle down enable it to float in the air, but it is the wind that carries it afar.

Some degree of local segregation exists whenever the members of a species produced in a given area are more likely to interbreed with each other than with those produced in surrounding areas, or whenever extraordinary dispersal plants a colony beyond the range of ordinary dispersal. In other words, when those produced in a given district are more nearly related with each other than with those produced in surrounding districts, there local segregation has existed.

There is one important respect in which spatial segregation differs from all other forms of environal segregation, namely, in its ordinary operation it does not depend directly upon diversity in the qualities and powers of the organism. The dispersion of the members of a species would not be prevented if each was exactly like every other; though of course if there were no power of variation, separate breeding would have no influence in producing divergence of character. It follows that every species is—or is more or less liable to be—affected by spatial segregation; and it often happens that other forms of segregation arise through the previous operation of this form; but as spatial segregation prevents organisms from crossing only when separated in space, it must always be re-enforced by other forms of segregation before well-defined species are produced that are capable of occupying the same district without inter-breeding. The vast majority of the divergent forms arising through local segregation are re-integrated with the surrounding forms, new divergences constantly coming in to take the place of the old; but if, during its brief period of local divergence, industrial or chronal segregation is introduced, the variety becomes more and more differentiated, and, as one after another the different forms of reflexive segregation arise, it passes into a well-defined species. There is however reason to believe that the order of events is often the reverse, reflexive forms of segregation being the cause of the first divergences.

As spatial segregation does not depend upon diversity in the qualities and powers of the organism, so also it does not usually result in distributing the organism in different localities according to their differences of endowment. The causes that produce it are primarily separative, not segregative.

Migration is produced by the natural powers of the organism, acting under the guidance of instincts that usually lead a group of individuals, capable of propagating the species, to migrate together; while the organisms that are most dependent on activities in the environment for their distribution, are usually distributed in the form of seeds or germs, any one of which is capable of developing into a complete community.

The causes of separation between the different sections, and of integration between the members of one section, are therefore sufficiently

clear, but what are the causes of difference of character in the different sections, especially when they are exposed to the same environment? These causes all come under what I call intensive segregation, which, for the sake of saving repetition, will be fully discussed in a separate paper.

### (*d*) *Fertilizational segregation.*

Since writing this chapter on environal segregation I have seen Francis Galton's short article on "The Origin of Varieties," published in *Nature*, vol. XXXIV, p. 395, in which he refers to a cause of segregation that had not occurred to me. He says: "If insects visited promiscuously the flowers of a variety and those of the parent stock, then, supposing the organs of reproduction and the period of flowering to be alike in both and that hybrids between them could be produced by artificial cross-fertilization, we should expect to find hybrids in abundance whenever members of the variety and those of the original stock occupied the same or closely contiguous districts. It is hard to account for our not doing so, except on the supposition that insects feel repugnance to visiting the plants interchangeably."

9. Following the form of nomenclature adopted in this paper, I venture to call this principle *fertilizational segregation.*

It is evident that segregation of this form depends on divergence of character already clearly established, and therefore on some other form of segregation that has preceded. It is also segregative rather than separative, in that it perpetuates a segregation previously produced, which might otherwise be obliterated by the distribution of the different forms in the same district. The form of segregation that precedes fertilizational segregation, producing the conditions on which it depends, must, from the nature of the case, be local segregation. Chronal and impregnational segregation, when imperfectly established, might be fortified by fertilizational segregation; but, in the case of plants, these are all dependent on previous local segregation.

### (*e*) *Artificial segregation.*

Artificial segregation is segregation arising from the relations in which the organism stands to the rational environment. As the operation of this cause is familiar, and as it was considered in the last chapter when discussing the effects of segregation, we pass on, simply calling attention to the fact that it is a form of environal segregation.

## THE IMPORTANCE OF ENVIRONAL SEGREGATION.

We must not assume that the various forms of environal segregation are of small influence in the formation of species because sexual or impregnational incompatibility is a more essential feature, without which all other distinctions are liable to be swept away. The importance of the forms of segregation discussed in this chapter lies in the fact

that they often open the way for the entrance of the more fundamental forms of segregation, even if they are not essential conditions for the development of the same. Though myriads of divergent forms produced by local and industrial segregations are swept away in the struggle for existence, and myriads are absorbed in the vast tides of crossing and inter-crossing currents of life, the power of any species to produce more and more highly adapted variations, and to segregate them in groups that become specially adapted to special ends, or that grow into specific forms of beauty and internal harmony, is largely dependent on these factors.

## CHAPTER IV.

### DESCRIPTION AND CLASSIFICATION OF THE CAUSES OF CUMULATIVE SEGREGATION (continued).

#### B. REFLEXIVE SEGREGATION.

Reflexive segregation is segregation arising from the relations in which the members of one species stand to each other.

It includes three classes, which I call conjunctional, impregnational, and institutional segregation.

It is important to observe that intergeneration requires compatibility in all the circle of relations in which the organism stands; but, in order to insure segregation between any two or more sections of a species, it is sufficient that incompatibilty should exist at but one point. If either sexual or social instincts do not accord, if structural or dimensional characters are not correlated, if the sexual elements are not mutually potential, or if fixed institutions hold groups apart, intergeneration is prevented, and se-generation is the result, either as segregation, or as separation that is gradually transformed into segregation.

#### (*a*) *Conjunctional segregation.*

Conjunctional segregation is segregation arising from the instincts by which organisms seek each other and hold together in more or less compact communities, or from the powers of growth and segmentation in connection with self-fertilization, through which similar results are gained.

I distinguish four forms, social, sexual, germinal, and floral segregation.

10. *Social segregation* is produced by the discriminative action of social instincts.

The law of social instinct is preference for that which is familiar in one's companions; and, as in most cases the greatest familiarity is gained with those that are near of kin, it tends to produce breeding within the clan, which is a form of segregate breeding. If the clan never grows beyond the powers of individual recognition, or if the

numbers never become so great as to impede each other in gaining sustenance, there will be but little occasion for segregation; but multiplication will lead to segmentation. Wherever the members of a species, ranging freely over a given area, divide up into separate herds, flocks, or swarms, of which the members produced in any one clan breed with each other more than with others, there we have social segregation.

It should always be kept in mind that social segregation arises at a very early stage, holding apart groups not at all or but very slightly differentiated; while in the case of many animals, the eager sexual instincts of the males constantly tend to break up these minor groups. Though the barriers raised by social instincts are often broken over, their influence is not wholly overcome; and in many instances the social segregation becomes more and more pronounced, till in time decided sexual segregation comes in to secure and strengthen the divergence.

11. *Sexual segregation* is produced by the discriminative action of sexual instincts.

There can be no doubt that sexual instincts often differ in such a way as to produce segregation. But how shall we account for these differences? In the case of social segregation there is no difficulty, for it seems to be, like migration, due to a constant instinct, always tending to segregation. We also see that an endowment which prevents the destruction of the species through the complete isolation of individuals, and which co-operates with migrational instincts in securing dispersal without extinction, may be perfected by the accumulating effects of its own action. And is there any greater difficulty in accounting for the law that regulates sexual instincts? If it can be shown that vigor and variation, the conditions on which adaptation depends, are in their turn dependent on some degree of crossing, there will be no difficulty in attributing the development of an instinct that secures the crossing to the superior success of the individuals that possess it in even a small degree. On the other hand, whenever there arises a variety that can maintain itself by crosses within the same variety, any variation of instinct that tends to segregation will be preserved by the segregation. It needs no experiments to prove that if the members of a species are impelled to consort only with the members of other species, they will either fail to leave offspring or their offspring will fail to inherit the characteristics of the species. The same is true concerning the continuance of a variety that is not otherwise segregated. The power of variation on the one hand, and the power of divergent accumulation of variations on the other hand, are prime necessities for creatures that are wresting a living from a vast and complex environment; and the former is secured by the advantage over rivals possessed by the variations that favor crossing, and the latter by the better escape from the swamping effect, and sometimes from the competition of certain rivals, secured by the more

segregative variations. We must therefore believe that whenever in the history of an organism there arise segregative variations which are able to secure sufficient sustentation and propagation to continue the species, the segregative quality of the forms thus endowed will be preserved and accumulated through the self-accumulating effect of the segregative endowments.

It is probable that in many of the higher vertebrates sexual instincts tend to bring together those of somewhat divergent character, but the difference preferred is within very narrow limits, and beyond those limits, it may be said that the general law for sexual attraction is that it varies inversely as the difference in the characters of the races represented, if not inversely as some power of such difference. The action of such a law is necessarily segregative, whenever the divergence has, through other causes, passed beyond the limit of higher attraction. Before sexual segregation can arise there must arise distinctive characteristics by means of which the members of any section may discriminate between those of their own and other sections. If there are no constant characteristics there can be no constant aversion between members of different groups, no constant preference of those of one's own group. From this it follows, that before sexual segregation can arise, some form of segregation that is not dependent on accumulated divergence of character must have produced the divergence on which the sexual segregation depends. Such forms are local, social, and some kinds of industrial segregation. When varieties have arisen through these causes it often happens that sexual segregation comes in and perpetuates the segregation which the initial causes can no longer sustain. As long as the groups are held apart by divergent sexual instincts, it is evident that divergent forms of sexual selection are almost sure to arise, leading to a further accumulation of the divergence initiated by the previous causes.

If there is any persistent cause by which local and social groups are broken up and promiscuously intermingled before recognizable characters are gained, the entrance of sexual segregation will be prevented. I therefore conclude that the chief influence of this latter factor is found in its prolonging and fortifying the separate breeding of varieties that have arisen under local, social, or industrial segregation, and in thus continuing the necessary condition for the development of increasingly divergent forms of intensive segregation, under which the organism passes by the laws of its own vital activity when dealing with a complex environment in groups that never cross.

12. *Germinal segregation* is caused by the propagation of the species by means of seeds or germs any one of which, when developed, forms a community so related that the members breed with each other more frequently than with the members of other communities. If the constitution of any species is such that the ovules produced from one seed are more likely to be reached and fertilized by pollen produced from

the same seed than by pollen produced from any other one seed, then germinal segregation is the result.

In order to secure this kind of segregation it is not necessary that the flowers fertilized by pollen from the same plant should be more fertile, or the seeds capable of producing more vigorous plants than the flowers fertilized by pollen from another plant. All that is required is that of the seeds produced a larger number shall be fertilized by the pollen of the same plant than by the pollen of any other one plant.

This form of segregation is closely related to local segregation on one side, and to social segregation on the other. It however differs from the former in that it does not depend on migration or transportation, and from the latter in that it does not depend on social instincts.

13. *Floral segregation* is segregation arising from the closest form of self-fertilization, namely, the fertilization of the ovules of a flower by pollen from the same flower.

Many plants that in their native haunts are frequently crossed by the visits of insects depend entirely on self-fertilization when transported to other countries where no insect is found to perform the same service for them. The common pea (*Pisum sativum*) is an example of a species that habitually fertilizes itself in England, though Darwin found that it was very rarely visited by insects that were capable of carrying the pollen.* Darwin also mentions *Ophrys apifera* as an orchid which "has almost certainly been propagated in a state of nature for thousands of generations without having been once intercrossed."†

A fact of great importance in its bearing on the origin of varieties should be here noted. Any variation, arising as a so-called sport, in any group of plants where either of these principals is acting strongly, will be restrained from crossing, and will be preserved except in so far as reversion takes place. Now there is always a possibility that some of the segregating branches of descent will not revert, and that through the special character which they possess in common, they will some time secure the services of some insect that will give them the benefit of cross-fertilization with each other without crossing with other varieties. The power of attaining new adaptations may be favored by self-fertilization, occasionally interrupted by inter-breeding with individuals of another stock; for the latter is favorable as introducing vigor and variation, and the former as giving opportunity for the accumulation of variations.

### (*b*) *Impregnational segregation.*

Impregnational segregation is due to the different relations in which the members of a species stand to each other in regard to the possibility of their producing fertile offspring when they consort together.

* See "Cross and self-fertilization in the vegetable kingdom," p. 161.

† See *ibidem*, p. 439.

In order that impregnational segregation should be established and perpetuated it is necessary: First, that variation should arise from which it results that those of one kind are capable of producing vigorous and fertile offspring in greater numbers when breeding with each other than when breeding with other kinds; second, that mutually compatible forms should be so brought together as to insure propagation through a series of generations. In order to secure this second condition it is necessary that, in the case of plants, there should be some degree of local, germinal, or floral segregation, and in the case of animals that pair, either pronounced local segregation, or partial local segregation supplemented by social or sexual segregation. The first of these factors I call negative segregation, as contrasted with all other forms of segregation, which I group together as positive segregation.

Of each form of segregation which we have up to this point considered, the segregating cause has been one that distributes individuals of the same species in groups between which free inter-generation is checked; while the propagation of the different groups depends simply on the original capacity for inter-generating common to all the members of the species. The inter-crossing has been limited not by the capacity but by the opportunity and inclination of the members. Coming now to cases in which the lack of capacity is the cause that checks the production of mongrels, we find a dependence of a very different kind; for to insure the propagation of the different groups it is not enough that the general opportunity for the members to meet and consort remains unimpaired. There must be some additional segregating influence bringing the members together in groups corresponding to their segregate capacity, or they will fail of being propagated.

A partial exception must be made in the case of potential and pre-potential segregation, the latter being due to the pre-potency of the pollen of a species or variety, on the stigma of the same species or variety and the former to the complete impotence of the foreign pollen. When allied species of plants are promiscuously distributed over the same districts, and flowering at the same time, pre-potency of this kind is one of the most direct and efficient causes of segregate breeding. The same must be true of varieties similarly distributed whenever this character begins to affect them. In the case, however, of diœcious plants and of plants whose ovules are incapable of being impregnated by pollen from the same plant, no single plant can propagate the species. If therefore the individuals so varying as to be pre-potent with each other are very few and are evenly distributed amongst a vast number of the original form, they will fail of being segregated through failing to receive any of the pre-potent pollen. It is thus apparent that when the mutually pre-potent form is represented by comparatively few individuals, their propagation without crossing will depend on their being self-fertile and subject to germinal or floral

segregation, or on their being brought together by some or other form of positive segregation.

When a considerable number of species of plants are commingled and are flowering at the same time, their separate propagation is preserved, in no small degree, by the pre-potential segregation of those that are most nearly allied, and by the complete potential segregation of those that belong to different families, orders, and classes. The same principle must come in to prevent the crossing of different species, genera, families, and orders of animals whose fertilizing elements are distributed in the water. We must therefore consider it a form of positive as well as negative segregation; for the free distribution of the fertilizing element, with the superior affinity of the two sexual elements when produced by those that are mutually pre-potential, secures the inter-breeding of those that are mutually pre-potential.

Impregnational segregation generally exists between the different species of the same genus, almost always between species of different genera, and always between species of different families, orders, classes, and all groups of higher grade. And in all these cases it is associated with other forms of segregation, and whenever it has once become complete, it has never been known to give way. Though complete mutual sterility never gives place to complete mutual fertility, in every case where the descendants of the same stock have developed into different classes or orders, and in most cases where they have developed into different families of genera, the reverse process has taken place, and complete mutual fertility has given place to complete mutual sterility.

Under impregnational segregation I distinguish five principles, namely, segregate size, segregate structure, potential and pre-potential segregation, segregate fecundity, and segregate vigor.

14. *Segregate size* is caused by incompatibility in size or dimensions. As familiar illustrations of this form of segregation, I may mention the following: The largest and smallest varieties of the ass may run in the same pasture without any chance of crossing. I have also kept Japanese bantam fowls in the same yard with other breeds without any crossing. In many other species individuals of extreme divergence in size are incapable of inter-breeding.

15. *Segregate structure* is caused by the lack of correlation in the proportionate size of different organs and by other incompatibilities of structure.

Darwin suggests that the impossibility of a cross between certain species may be due to a lack of correspondence in length of the pollen tubes and pistils. Such a lack of harmony would perhaps account for difference of fertility in reciprocal crosses.

Segregate structure does not usually arise till other forms of segregation have become so well established that difference of structure does not make any essential difference in the amount of inter-generation.

It is not however impossible that species that would otherwise be fertile *inter se* are thus held apart. In Broca's work on "Human Hybridity"* there is a passage quoted from Prof. Serres, showing that it is very possible that this form of incompatibility may exist between certain races of man.

16. *Potential segregation and pre-potential segregation.*—These are caused by more or less free distribution of the fertilizing element, together with the greater rapidity and power with which the sexual elements of the same species, race, or individual combine, as contrasted with the rapidity and power with which the elements of different species, races, or individuals combine. Potential segregation is caused by the mutual impotence of the contrasted forms, as is always the case between different orders and classes, and pre-potential segregation is caused by the superior influence of the fertilizing element from the same species, race, or individual, as contrasted with that from any other species, race, or individual, when both are applied to the same female at the same time, or sometimes when the prepotent element is applied many hours after the other.

For the operation of this principal the fertilizing element from different males must be brought to the same female.

When pollen from a contrasted genus, order, or class has no more effect than inorganic dust, it seems appropriate that we should call the result potential segregation rather than pre-potential segregation, which implies that the foreign as well as the home pollen is capable of producing impregnation. Pre-potential segregation may be considered the initial form of potential segregation, the former passing through innumerable grades of intensity in the latter. We may therefore consider the principles as fundamentally one, though it will be convenient to retain both names.

The importance of this principle in producing and preserving the diversities of the vegetable kingdom can hardly be overstated. If pollen of every kind were equally potent on every stigma what would the result be? What distinctions would remain? And if potential segregation is necessary for the preservation of distinctions, is it not equally necessary for their production? Amongst water animals that do not pair the same principle of segregation is probably of equal importance. Concerning this form of segregation many questions of great interest suggest themselves, answers to which are not found in any investigations with which I am acquainted. Some of these questions are as follows:

(1) Are there many cases of pre-potential as well as of potential segregation between different forms of water animals?

(2) Is pre-potential segregation always accompanied by segregate fecundity and segregate vigor?

* English translation published by the Anthropological Society of London, p. 28.

(3) If not always associated, which of the three principles first appears, and what are their relations to each other?

(4) When allied organisms are separated by complete environal segregation are they less liable to be separated by these three principles?

Darwin has in several places referred to the influence of pre-potency in pollen, and in two places I have found reference to the form of pre-potency that produces segregation; but I find no intimation that he regarded this or any other form of segregation as a cause of divergent evolution, or as a necessary condition for the operation of causes producing divergent evolution. The effect of pre-potency in pollen from another plant in preventing self-fertilization is considered in the tenth chapter of his work on "Cross and self fertilization in the vegetable kingdom," pp. 391–400. Some very remarkable observations concerning the pre-potency of pollen from another variety from that in which the stigma grows, are recorded in the same chapter; but no reference is there made to the effect that must be produced when the pollen of each variety is pre-potent on the stigma of the same variety. In the sixteenth chapter of "Variation under Domestication" it is suggested that pre-potency of this kind might be a cause of different varieties of double hollyhock reproducing themselves truly when growing in one bed; though there was another cause to which the freedom from crossing in this case had been attributed. Again, in chapter viii of the fifth edition* of the "The origin of species," in the section on "The origin and causes of sterility," Darwin, while maintaining that the mutual sterility of species is not due to natural selection, refers to pre-potency of the kind we are now considering as a quality which, occurring in ever so slight a degree, would prevent deterioration of character, and which would therefore be an advantage to a species in the process of formation, and accordingly subject to accumulation through natural selection. In order to construct a possible theory for the introduction of sterility between allied species by means of natural selection, he finds it necessary simply to add the supposition that sterility is directly caused by this pre-potency. He however for several reasons concludes that there is no such dependence of mutual sterility on the process of natural selection. Concerning the pre-potency he makes no reservation, and I accordingly judge that he continued to regard it as strengthened and developed through the action of natural selection.

It is concerning this last point that I wish to give reasons for a different opinion. I believe that qualities simply producing segregation can never be accumulated by natural selection, for—

(1) When separate generation comes in between two sections of a species they cease to be one aggregate, subject to modification through the elimination of certain parts. Both will be subject to similar forms of natural selection only so long as the circumstances of both and the

* Since my comments on this passage were written, I have discovered that Darwin has omitted it from the sixth edition.

variations of both are nearly the same, but they will no longer be the members of one body between which the selecting process is carried out. On the contrary, if they occupy the same district each group will stand in the relation of environment to the other, modifying it and being modified by it, without mutually sharing in the same modification.

(2) Though one may exterminate the other, the change that comes to the successful group through the contest is not due to its superiority over the other, but to the superiority of some of its own members over others.

(3) When any segregate form begins to arise we can not attribute its success to the advantage of se-generation, for the inter-generating forms are at the same time equally successful; wherefore it is not the success, but the separateness of the success, that is due to the se-generation.

(4) The continuance of the descendants of a group in a special form will depend on its segregation, but this is a very different thing from the special success of its descendants. The preservation of a *special kind* of adaptation is never due to natural selection, which is the superior success of the higher *degrees* of adaptation of every kind.

(5) The power of migration, or any other power directly related to the environment, may be accumulated by natural selection, and afterward lead to segregation, but, according to my method of judging, the continuous advantage of segregation over integration can never be shown, for both are equally essential in the economy of nature; and though one process may at one time predominate over the other, the comparative advantage of segregation, if there be such advantage, can not be the cause of the preservation of forms endowed with segregative qualities, for they will certainly be preserved as long as they are able to win a bare existence, which is often a lower grade of success than the one from which they are passing.

(6) According to my view, instead of the accumulation of the segregative pre-potency depending on natural selection, the accumulation of divergent forms of natural selection depends on some form of segregation.

But if the accumulation of pre-potential segregation is not due to natural selection, how shall we explain it? It is I think due to the fact that those forms that have the most of this character are, through its action, caused to breed together. We have already seen, when considering seasonal and sexual segregation, that if segregation is directly produced by the instincts or physiological constitution of the organism, there is a tendency toward an increasing manifestation of the character in successive generations. Those that have but a slight degree of segregate pre-potency eventually coalesce, forming one race, while those possessing the same character in a higher degree remain more distinct, and their descendents become still more segregagate and still more permanently divergent. As long as the segregate

forms are able to maintain vigor and secure fair sustentation, the process continues and the separation becomes more pronounced. Of this form of the law of cumulative segregation we may say, that as the descendants of the best fitted necessarily generate with each other and produce those still better fitted, so the descendants of those possessing the most segregative endowments necessarily generate with each other and produce those that are still more segregate.

It may at first appear that a slight degree of pre-potence will prevent crossing as effectually as a higher degree; but further reflection will show that the efficiency of the prevention will vary in direct proportion with the length of time over which the pre-potent pollen is able to show its pre-potence, and this will allow of innumerable grades. If, in the case of certain individuals, the pre-potency is measured by about twenty minutes, while with other individuals it enables the pollen of the same variety to prevail, though reaching the stigma an hour after the pollen of another variety has been applied, the difference in the degree of segregation will be sufficient to make the persistence of the latter much more probable than that of the former. This form of segregation is evidently one of the important causes preventing the free crossing of different species of plants. It probably has but little influence on terrestrial animals, but how far it is the cause of segregation among aquatic animals is a question of no small interest, concerning which I have but small means for judging. I have however no hesitation in predicting that, unless we make the presence of this segregative quality the occasion for insisting that the forms so affected belong to different species, we shall find that amongst plants the varieties of the same species are often more or less separated from each other in this way. I do not know of any experiments that have been directed toward the determining of this point, but on the general principle that physiological evolution is not usually abrupt, and that race distinctions are the initial forms under which specific differences present themselves, I can have no doubt that feeble pre-potence precedes that which is more pronounced, and that part of this divergence in many cases takes place, while the divergent branches may be properly classed as varieties. Another reason for believing that pre-potential segregation will be found on further investigation to exist in some cases between varieties, is the constancy with which, in the case of species, this character is associated with segregate fecundity and segregate vigor, which we know are sometimes characteristics of varieties in their relation to each other. The importance of these latter principles when occurring in connection with different forms of partial segregation will now be considered.

17, 18. *Segregate fecundity and segregate vigor.*—By segregate fecundity I mean neither segregation produced by fecundity nor fecundity produced by segregation, but the relation in which species or varieties stand to each other when the inter-generation of members of the

same species or variety results in higher fertility than the crossing of different species or varieties. In like manner segregate vigor is the relation in which species or varieties stand to each other when the inter-generation of members of the same species or variety produces offspring more vigorous than those produced by crossing with other species or varieties. Integrate fecundity and integrate vigor are the terms by which I indicate the relation to each other of forms in which the highest fertility and vigor are produced by crossing, and not by independent generation.

Before discussing these principles through which the influence of segregation is greatly increased, it will be an advantage if we can gain some idea of the nature of cumulative fertility in its relations to a law of still wider import. I refer to the fourfold law of antagonistic increase and mutual limitation between (1) integration, (2) segregation, (3) adaptation, (4) multiplication—in other words, between (1) general invigoration and power of variation through crossing, (2) the opening of new opportunities and independent possibilities, (3) special adaptation to present circumstances, (4) powers of multiplied individualization. Darwin has considered at length the first and third, though I do not remember that he has anywhere pointed out that their development is due to a kind of self-augmentation. I believe this is so emphatically the case that the former might well be called the law of self-cumulative vigor, and the latter the law of self-cumulative adaptation. Corresponding to these two laws, I find the additional laws of self-cumulative segregation and self-cumulative fertility. Darwin's theory, that diversity of natural selection is directly and necessarily dependent on exposure to different external conditions tends to obscure, though not to deny, the fact that the breeding together of the better adapted, which causes the increase of adaptation, is due to the different degrees of endowment in the organism, rather than to diversity in the environment. It is also true of segregative endowment and of fertility that they are necessarily cumulative whenever they belong in different degrees to members of the same intergenerant that are equally fitted. The cumulation of vigor, as that of adaptation, is I think rightly classed as a form of selection; for in both cases it depends on the power of the more highly endowed to supplant the less endowed without allowing them full opportunity to propagate; but the increase of segregative endowments and of fertility is due to principles quite different from this, and differing from each other. The segregative endowments augment through the inherent tendency of the more highly endowed to breed more exclusively with those of the same form, and therefore in the long run to breed more exclusively with each other; while the fertility of the more fertile neither drives out the less fertile nor holds the two classes apart, but simply multiplies the offspring of the more fertile, making it sure that in each generation they will predominate.

But all these forms of augmentation correspond, in that they secure

the breeding together of those possessing higher degrees of the special endowment, and so increase the average endowment, either of the whole number of the offspring or of the segregated portion. Vigor increases through the breeding together of the more vigorous, resulting from their overcoming and crowding out the less vigorous without allowing them full opportunity to propagate. Adaptation increases through the breeding together of the better adapted, resulting from their supplanting their rivals without allowing them full opportunity to propagate. Segregative endowments increase through the breeding together of the more highly endowed, resulting from the fact that as long as segregation is incomplete more than half of each generation of pure descent are necessarily the offspring of parents whose segregative endowments were above the average. Fertility increases through the breeding together of the more fertile, resulting from the fact that more than half of each generation are the offspring of parents of more than average fertility. As the breeding together of the more vigorous and the better adapted, caused by their superior success, tends to increase and intensify the vigor and adaptation of successive generations, so the breeding together of those more highly endowed with segregative powers, caused by the segregation, tends to strengthen and intensify the segregative powers in successive generations; and so the breeding together of the more fertile, caused by the larger proportion of offspring produced by the more fertile, tends to increase the fertility of successive generations. Among those that would be equally productive if equally nourished, the ratio of propagation varies directly as the degree of sustentation above a certain minimum (and perhaps below a certain maximum), and therefore directly as the degree of adaptation that secures this sustentation. This ***propagation according to degrees of adaptation to the environment is what I understand by natural selection.*** But among those that are equally adapted to the environment the ratio of propagation varies directly as the ratio of fertility. This ***propagation according to degrees of fertility is what I call the law of cumulative fertility.*** It is not due to different degrees of success, or to any advantage which the individuals of one form have over those of other forms; but simply to the higher ratio of multiplication in the more fertile forms securing the inter-generation of the more fertile. ***In connection with natural selection it insures, in the descendants, the predominance of the better adapted of the more fertile and the more fertile of the better adapted.***

At the close of the previous chapter I called attention to the fact that innumerable local segregations and other imperfect forms of se-generation are being constantly broken down, partly by the increase of numbers and partly by the superior fertility and vigor of offspring produced by crossing. It seems to be a fundamental law that vigor and variation in the offspring depend on some degree of diversity of constitution in the parents, and diversity of constitution that is not

entirely fluctuating depends on some degree of positive segregation; therefore vigor and variation depend on the breaking down of incipient segregations, and on the interfusion of the slightly divergent forms that had been partially segregated. But in the history of every race that is winning success by its vigor and variation there is liable to come a time when some variety, inheriting sufficient vigor to sustain itself, even if limited to the benefits of crossing with the individuals of the same variety, becomes partially segregated. As we have already seen, segregation, in so far as it depends on the qualities of the organism, tends ever to become more and more intense; but, in the very nature of things, not only will the segregation be for many generations only partial, but partial segregation, though it may greatly delay the submerging of different groups in one common group, will never prevent that result being finally reached. Though the siphon that connects two tanks of water be ever so small, the water will in time find a common level in both tanks, unless there are additions or subtractions of water that prevent such a result. So, in the case under consideration, final fusion will take place, unless differentiation progresses more rapidly than the fusion, or some other influence comes in to counteract the levelling influence of occasional crosses. If, under such conditions, some branch of the partially segregated variety becomes more fertile when generating with members of the same variety, and less fertile when generating with other varieties, a principle will be introduced tending to strengthen any form of partial segregation that already exists between the varieties. This principle when co-operating with partial segregation will produce pure masses of each variety, when, without the action of this principle, all distinctions would be absorbed by the crossing. We know that a transition from integrate fecundity to segregate fecundity usually takes place at a point in the history of evolution intermediate between the formation of an incipient variety and a strongly-marked species; and though the causes that produce this transition may be very difficult to trace, I believe the results that must follow can be pointed out with considerable clearness and certainty.

Darwin's investigations have shown that in many cases, if not in the majority, the relation of varieties to each other is that which I have called integrate fecundity and integrate vigor; that is, the highest fertility is attained when varieties are crossed, and the vigor of offspring thus produced is greater than when the inter-generation is within the limits of one variety. He, however, gives in "Variation under domestication," chapter xvi, some special cases, in which "varieties of the same species behave, when crossed, like closely allied but distinct species;" and remarks that similar cases "may not be of very rare occurrence, for the subject has not been attended to." The same cases are also mentioned in all the editions of the "Origin of Species."*

* See 1st edition, p. 238; 5th edition, p. 259; 6th edition, p. 258.

The problems that arise in considering the different results produced by different degrees of positive segregation and segregrate fecundity are of a nature suitable for mathematical treatment. Before, however, computing the effects of segregate fecundity when co-operating with positive segregation, it will be in place to show that it is of itself only a negative form of segregation, having no power to insure the propagation of the varieties thus characterized, though they are fully adapted to the environment. This is most easily brought to light by considering the effect of a high degree of this quality when positive segregation is entirely wanting, or when it is sufficient to give simply a chance of segregate breeding by bringing each individual near to its natural mate. For example, let us suppose, first, that a male and a female each of several allied but mutually sterile species are brought together on one small island, all other tendencies to positive segregation being removed, while mutual sterilty still remains; second, that a male and female when once mated remain together for the breeding season; and third, that all find mates. Now, if we have seven species, each represented by one individual of each sex, what is the probability that all the species will be propagated? And what the probability for the propagation of none, or of but one, or of but two, or of but three of the species? The answers, as I have computed them, are as follows: The probability that none will be propagated is $\frac{1854}{5040}$; that one species will be is $\frac{1855}{5040}$; that two species $\frac{924}{5040}$; that three species $\frac{315}{5040}$; that four species $\frac{70}{5040}$; that five species $\frac{21}{5040}$; that seven species $\frac{1}{5040}$. These numerators are found in the seventh line of a table that I call the Permutational Triangle. If we have ten species, the probability that in any one trial no species will match truly and be propagated is $\frac{1334961}{3628800}$; that one species will match truly and propagate is $\frac{1334960}{3628800}$; that ten will is $\frac{1}{3628800}$. This means that if 3,628,800 trials are made, one of them will probably be a case in which each male pairs with the female of the same species, while 1,334,961 will be cases in which none are so matched, and 1,334,960 will be cases in which one pair is so matched. It therefore appears that more than eight-elevenths of the probabilities are against the continuance of more than one of the ten species.

There will perhaps be some hesitation in receiving these figures before I have given the method by which the results have been reached; but the necessary length of this paper, even when restricted to the briefest discussion of general principles, induces me to reserve my computations for another occasion. It is not however necessary to have a complete solution of this problem, in order to reach the conclusion that the origin of separate races and species depends not only upon their adaptation to the environment and their mutual sterility when crossing with each other, but also upon their positive segregation. We can further see (when considering an extreme case, like either of the above supposed cases) that segregate fecundity, without the aid of positive

segregation, must lead to extinction. We have already seen that partial segregation can not by itself prevent the fusion of species. It therefore follows that in order to account for the continuance of divergent races we must suppose either that the segregation is complete or that the divergent evolution is strong enough to more than counterbalance the influence of the occasional crossing, or that the partial segregation is aided by segregate fecundity or segregate vigor.

Between the members of species belonging to different orders we find not only complete segregation, but complete sterility when attempts at crossing are made; but hope of gaining an explanation of how these characteristics have arisen is found, not in the study of those cases in which the process has been completed, but in the study of the relations to each other of species and varieties that are characterized by partial segregation and mutual sterility, that is not complete. Here again mathematical analysis will help us in understanding the subject. Though I have not succeeded in constructing a complete mathematical representation of all the grades of intermingling that will take place, I have found a general formula that gives a close approximation to the proportion in which two species will breed pure as contrasted with the proportion of first crosses and their descendants that will be produced, in any case in which the degree of segregation and the ratios of fertility for the pure and cross breeds are known. As my object is simply to show under what conditions the pure races will continue without being swamped by crossing, it is not necessary that I should follow the action and reaction between the three-quarter breeds. I wish however to call attention to the fact that when the number of the pure forms and of the half-breeds is constantly decreasing, without a general decrease in the sum of the descendants, it is evident that the three-quarter breeds and their descendants are increasing; and when a three-quarter breed on one side crosses with a three-quarter breed on the other side, the offspring will usually be about intermediate between the two species; therefore, where the two species are equally numerous, if we find that the pure forms will disappear through fusion, we may expect that the three-quarter breeds will also disappear through fusion.

In constructing my formula it was found necessary to commence by placing in the 1st generation of the half-breeds a more or less arbitrary symbol; for the true symbol in each case is the final one reached in the $n$th generation when $n$ is a very high number. The chief interest therefore centers in what can be accomplished through the use of this formula for the $n$th generation. It seems to me to furnish a method of reaching the final proportion of pure breeding that will be produced by any form of combination between positive segregation and segregate fecundity, and to give results that would require thousands of years of continuous experimenting to reach in any other way.

TABLE I.—*Arithmetical computation, showing the number of half-breeds as contrasted with the pure-breeds, when $\frac{9}{10}$ of each variety form unions among themselves and double with each generation, while the offspring of the $\frac{1}{10}$ that form mixed unions simply equal the number of the parents by which they are produced, in other words when $c = \frac{1}{10}$, $M = 2$, $m = 1$ (see Table II).*

| Variety No. 1, pure-breeds. | | | | Of what generation. | Half of the half-breeds. | Three-quarter breeds on one side. | Variety No. 2, pure-breeds. |
|---|---|---|---|---|---|---|---|
| 1,000 | = | A | = | Initial number.... | ............. | ............. | 1,000 |
| 1·8 | | | | | | | |
| 1,800 | = | A (1·8) | = | 1st generation .... | 100 | ............. | 1,800 |
| 1·8 | | | | | | | |
| 3,240 | = | A $(1{\cdot}8)^2$ | = | 2nd generation.... | 260 | 20 | 3,240 |
| 1·8 | | | | | | | |
| 5,832 | = | A $(1{\cdot}8)^3$ | = | 3rd generation .... | 532 | 72 | 5,832 |
| $357{\cdot}05 = (1{\cdot}8)^{10}$ computed by log. | | | | | | | |
| ∴ 357,050 | = | A $(1{\cdot}8)^{10}$ | = | 10th generation ... | 35,688 | ............. | 357,050 |
| $39,347{\cdot}272 = (1{\cdot}8)^{18}$ | | | | | | | |
| ∴ 39,347,272 | = | A $(1{\cdot}8)^{18}$ | = | 18th generation... | 3,934,725 | ............. | 39,347,272 |

EXPLANATION OF TABLE I.—The second generation of the half-breeds is found by taking $\frac{9}{10}$ of the previous half-breeds, *i. e.* $100 \times \frac{9}{10} = 90$, and $\frac{1}{10}$ of the previous pure-breeds (the $\frac{1}{10}$ that form mixed unions), minus $\frac{1}{10}$ of the previous half-breeds (because $\frac{1}{10}$ of the half-breeds consort with an equal number of pure-breeds, and so produce not half-breeds but three-quarter-breeds), *i. e.* $180 - 10 = 170$. Adding these two sums together we have $90 + 170 = 260 =$ the second generation of half-breeds.

As in this table the computation commences without any half-breeds, the following generations of half-breeds are all a little less than $\frac{1}{10}$ as large as the corresponding generations of pure-breeds. When, however, we come to the eighteenth generation the difference is less than one in a million, and we may consider the result as practically corresponding with the formula for the *n*th generation, given in Table III.

The three-quarter-breeds are obtained by multiplying $\frac{1}{10}$ of the previous generation of half-breeds by 2, and adding to the result the sum of the previous generations of three-quarter-breeds. This of course gives a number too large; for some of the three-quarter-breeds will fail to breed with three-quarter-breeds. A closer expression of the proportion between pure-breeds and three-quarter-breeds is given in Tables VII and VIII.

**TABLE II.**—*Preliminary Formula for showing the Proportion of Half-breeds to Pure-breeds.*

Let R = the ratio of pure breeding, *i. e.*, the segregation.

Let $c$ = the ratio of cross-breeding.

*Ex.* When $\frac{9}{10}$ of the unions are within the limits of the species and $\frac{1}{10}$ of the unions are with an allied species $R = \frac{9}{10}$, $c = \frac{1}{10}$. R will always equal $1 - c$.

Let M = the ratio of fertility in each generation for those that breed with their own kind.

Let $m$ = the ratio of fertility in each generation for the cross-unions and for the hybrids when breeding together.

Let A = the initial number of individuals representing the pure species when the computation commences.

| Number of individuals representing the pure form. | Number of individuals representing the half-breeds. |
|---|---|
| A = Initial number. | |
| A(RM) = 1st generation | 1st generation = $Acm$. |
| $A(RM)^2$ = 2nd generation | 2nd generation = $(AcmR + A(RM)c - Acmc) \times m$.* |
| $A(RM)^3$ = 3rd generation | 2nd generation = $(AcmR - Acmc)m + Acm(RM)$. |
| $A(RM)^4$ = 4th generation | 2nd generation = $Acm(R - c)m + Acm(RM)$. |
| Substituting $(1-c)$ for R in the 2nd gen., we have | Substituting in this $(1-c)$ for R, we have |
| $A(M - Mc)^2$ = 2nd generation. | 2nd generation = $Acm(1-2c)m + Acm(M - Mc)$. |

*The term $AcmR$ represents the number of half-breeds that form unions among themselves, the offspring being half-breeds; $A(RM)c$ represents the total number of pure-breeds of the first generation that formed mixed unions; of these $Acmc$ form unions with an equal number of half-breeds, and their offspring being three-quarter-breeds must be rejected; the remainder, namely $A(RM)c - Acmc$, form unions with the other race, and their offspring are half-breeds of the second generation.

**TABLE III.**—*Developed Formula for Segregation and Segregate Fecundity, giving the proportion of Half-Breeds to Pure-breeds.*

| Pure-breeds. | Half-breeds. |
|---|---|
| A = Initial number. | |
| $A(M - Mc)$ = 1st generation | 1st generation = $Amc$. |
| $A(M - Mc)^2$ = 2nd generation | 2nd generation = $Amc(1-2c)m + Acm(M - Mc)$. |
| $A(M - Mc)^3$ = 3rd generation | 3rd generation = $Amc((1-2c)m)^2 + Acm(M - Mc)(1-2c)m + Acm(M - Mc)^2$. |
| $A(M - Mc)^4$ = 4th generation | 4th generation = $Amc((1-2c)m)^3 + Acm(M - Mc)((1-2c)m)^2 + Acm(M - Mc)^2(1-2c)m + Acm(M - Mc)^3$. |
| | 4th generation = $Amc(M - Mc)^3\left(\frac{((1-2c)m)^3}{(M - Mc)^3} + \frac{((1-2c)m)^2}{(M - Mc)^2} + \frac{(1-2c)m}{(M - Mc)} + \frac{(M - Mc)^3}{(M - Mc)^3}\right)$. |
| $A(M - Mc)^n$ = $n$th generation | $n$th generation = $Amc(M - Mc)^{n-1} \times \left((\ \ )^{n-1} + (\ \ ) + (\ \ )^3 + (\ \ )^2 + \left(\frac{(1-2c)m}{M - Mc}\right)^1 + 1\right)$. |

*First rule.*—The pure-breeds of any generation are found by multiplying the previous generation of pure-breeds by $M - Mc$, and the half-breeds of any generation are found by multiplying the previous generation of half-breeds by $(1-2c)m$ and adding the previous generation of pure-breeds multiplied by $cm$.

*Second rule.*—The $n$th generation of pure-breeds$=A(M-Mc)^n=A(M-Mc)^{n-1}\times(M-Mc)$; and the $n$th generation of half-breeds$=Amc(M-Mc)^{n-1}$ multiplied by the sum $\Sigma$ of the series $1+\frac{(1-2c)m}{M-Mc}+\ldots$, containing as many terms as that expressed by the number of the generation, *i. e.*, containing $n$ terms, of which the first is 1; $\therefore\frac{H}{P}=\frac{mc}{M-Mc}\Sigma\left(1+\frac{(1-2c)m}{M-Mc}+\ldots\right)$; H being the number of half-breeds, and P being the number of pure-breeds.

*Third rule.*—To correct this formula, so that it shall indicate the proportions that will result when the relative vigor of pure and cross breeds is considered, we must substitute MV for M, and $mv$ for $m$; V being the proportion of each generation of pure breeds that grow to maturity and propagate, and $v$ being the proportion of half-breeds that do the same.

METHOD OF USING TABLE III.

By supposing $n$ to be an indefinitely high number, and by giving different values to M, $m$, and $c$, we shall have the means of contrasting the number of the pure-breeds with that of the half-breeds, when the process has been long continued under different degrees of positive segregation and segregate fecundity.

In the first place, let us take a case in which there is no segregate fecundity, that is $M=m$; and for convenience in computation let us make $M=1$, $m=1$. In every case where $m$ is not larger than M the fraction $\frac{(1-2c)m}{M-Mc}$ is less than unity, and the sum of the geometrical progression of our formula will fall within the limits of a number that can be easily computed by the well-known formula $S=\frac{a}{1-q}$, in which $a$ is the first number of the progression, which in this case is 1, and $q$ is the fraction we are now considering. Supposing $c=\frac{1}{10}$, the fraction will be $\frac{(1-\frac{2}{10})1}{1-\frac{1}{10}}=\frac{8}{9}=q$, $\therefore$ $S=\frac{a}{1-q}$ becomes $S=\frac{1}{1-\frac{8}{9}}=\frac{9}{9-8}=9$. This number 9 is therefore equal to the sum of this progression and can, therefore, be used as the value of the infinite progression in the formula for the $n$th generation when $n$ is a very high number. Substituting these values we find that the $n$th generation of the half-breeds equals the $n$th generation of the pure forms, each being equal to $\frac{9}{10}$ of A $(M-Mc)^{n-1}$. A $(M-Mc)^{n-1}$ is a vanishing quantity, for $M-Mc$ is less than 1. Every form is therefore in time fused with other forms. But let us try higher degrees of segregation. If we make $c=\frac{1}{100}$ or $\frac{1}{1000}$, we still find that half-breeds=pure-breeds, while the latter are constantly decreasing, which shows that imperfect positive segregation, without the aid of some quality like segregate fecundity, can not prevent a species being finally fused with other species as long as the whole number of each successive generation does not increase.

Let us now consider cases in which the Segregation is incomplete, but Segregate Fecundity comes in to modify the result. Let $M=2$, $m=1$, $c=\frac{1}{10}$. Substituting these values in our formula, we shall find that

the sum of the infinite progression is $\frac{9}{5}=\frac{18}{10}$. And $M-Mc=\frac{18}{10}$, which makes the half-breeds=the pure forms$\times cm$; and $cm=\frac{1}{10}$. Let $M=2$, $m=1$, $c=\frac{1}{100}$; then half-breeds=pure forms$\times\frac{1}{100}$. Let $M=2$, $m=1$, $c=\frac{1}{2}$; then the infinite progression=1, $M-Mc=1$, and the pure forms in each generation will equal A, and the half-breeds $A\times\frac{1}{2}$. Therefore Half-breeds=Pure-breeds$\times\frac{1}{2}$.

Let $M=3$, $m=2$, $c=\frac{1}{2}$; then the sum of the infinite progression=1, and the Half-breeds$=\frac{1}{2}\times 2\times A(M-Mc)_{n-1}$, and the Pure-breeds$=1\frac{1}{2}\times A(M-Mc)_{n-1}$; therefore Half-breeds=Pure-breeds$\times\frac{2}{3}$.

Let $M=3$, $m=2$, $c=\frac{1}{3}$; then Half-breeds=Pure breeds$\times\frac{2}{4}$.

Let $M=3$, $m=2$, $c=\frac{1}{4}$; then Half-breeds=Pure-breeds$\times\frac{2}{5}$.

Let $M=3$, $m=2$, $c=\frac{1}{5}$; then Half-breeds=Pure-breeds$\times\frac{2}{6}$.

Let $M=3$, $m=2$, $c=\frac{1}{10}$; then Half-breeds=Pure-breeds$\times\frac{2}{11}$.

Let $M=3$, $m=2$, $c=\frac{1}{100}$; then Half-breeds=Pure-breeds$\times\frac{2}{101}$.

TABLE IV.—*Simplified Formulas for the Proportions in which Half-breeds and Three-quarter-breeds stand to Pure-breeds when all are equally vigorous.*

From Table III we learn that

$$\frac{H}{P}=\frac{mc}{M-Mc}\times\left(1+\frac{(1-2c)m}{M-Mc}+\ .\ \ .\ \ .\ \right).$$

When $(1-2c)m$ is less than $M-Mc$, the series within the brackets is a decreasing geometrical progression, and we may obtain the value of the whole series by the formula $S=\frac{a}{1-q}$. Applying this formula, we have

$$\frac{H}{P}=\frac{mc}{M-Mc}\times\frac{1}{1-\frac{(1-2c)}{M-Mc}}=\frac{mc}{M-Mc}\times\frac{M-Mc}{M-Mc-m+2mc}=\frac{mc}{M-m+(2m-M)c}\ ..(1)$$

$$\therefore\ H=P\times\frac{mc}{M-m+(2m-M)c}\ \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

If $m'$ = the ratio of fertility for the Three-quarter-breeds, then according to the reasoning given in Tables VII and VIII,

$$\frac{T}{H}=\frac{2m'c}{M-m'+(2m'-M)c}\ ;\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

and

$$\frac{T}{P}=\frac{H}{P}\times\frac{T}{H}\ \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

The following solutions, as well as those given in Table V, are obtained by substituting values for M, $m$, and $c$ in formula (2):

When $M=4$, $m=3$, then if

$c=\frac{1}{2}$, half-breeds = pure-breeds $\times\ \frac{3}{4}$,
$c=\frac{1}{3}$, half-breeds = pure-breeds $\times\ \frac{3}{5}$,
$c=\frac{1}{4}$, half-breeds = pure-breeds $\times\ \frac{3}{6}$,
$c=\frac{1}{5}$, half-breeds = pure-breeds $\times\ \frac{3}{7}$,
$c=\frac{1}{6}$, half-breeds = pure-breeds $\times\ \frac{3}{8}$,
$c=\frac{1}{7}$, half-breeds = pure-breeds $\times\ \frac{3}{9}$,
$c=\frac{1}{8}$, half-breeds = pure-breeds $\times\ \frac{3}{10}$,
$c=\frac{1}{9}$, half-breeds = pure-breeds $\times\ \frac{3}{11}$,
$c=\frac{1}{10}$, half-breeds = pure-breeds $\times\ \frac{3}{12}$,
$c=\frac{1}{100}$, half-breeds = pure-breeds $\times\ \frac{3}{102}$.

When M = 5, $m$ = 4, then if

$c = \frac{1}{2}$, half-breeds = pure-breeds × $\frac{4}{5}$.
$c = \frac{1}{3}$, half-breeds = pure-breeds × $\frac{4}{6}$.
$c = \frac{1}{4}$, half-breeds = pure breeds × $\frac{4}{7}$.
$c = \frac{1}{5}$, half-breeds = pure-breeds × $\frac{4}{8}$.
$c = \frac{1}{6}$, half-breeds = pure-breeds × $\frac{4}{9}$,
$c = \frac{1}{7}$, half-breeds = pure-breeds × $\frac{4}{10}$.
$c = \frac{1}{8}$, half-breeds = pure-breeds × $\frac{4}{11}$,
$c = \frac{1}{9}$, half-breeds = pure-breeds × $\frac{4}{12}$,
$c = \frac{1}{10}$, half-breeds = pure-breeds × $\frac{4}{13}$,
$c = \frac{1}{100}$, half-breeds = pure-breeds × $\frac{4}{103}$.
$c = \frac{1}{1000}$, half-breeds = pure-breeds × $\frac{4}{1003}$.

TABLE V.

| | When M=10, and— | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $m$=9; | $m$=8; | $m$=7; | $m$=6; | $m$=5; | $m$=4; | $m$=3; | $m$=2; | $m$=1. |
| If $c=\frac{1}{2}$, then Half-breeds = Pure-breeds × | $\frac{9}{10}$ | $\frac{8}{10}$ | $\frac{7}{10}$ | $\frac{6}{10}$ | $\frac{5}{10}$ | $\frac{4}{10}$ | $\frac{3}{10}$ | $\frac{2}{10}$ | $\frac{1}{10}$ |
| If $c=\frac{1}{3}$, H = P× .......... | $\frac{9}{11}$ | $\frac{8}{12}$ | $\frac{7}{13}$ | $\frac{6}{14}$ | $\frac{5}{15}$ | $\frac{4}{16}$ | $\frac{3}{17}$ | $\frac{2}{18}$ | $\frac{1}{19}$ |
| If $c=\frac{1}{4}$, H = P× .......... | $\frac{9}{12}$ | $\frac{8}{14}$ | $\frac{7}{16}$ | $\frac{6}{18}$ | $\frac{5}{20}$ | $\frac{4}{22}$ | $\frac{3}{24}$ | $\frac{2}{26}$ | $\frac{1}{28}$ |
| If $c=\frac{1}{5}$, H = P× .......... | $\frac{9}{13}$ | $\frac{8}{16}$ | $\frac{7}{19}$ | $\frac{6}{22}$ | $\frac{5}{25}$ | $\frac{4}{28}$ | $\frac{3}{31}$ | $\frac{2}{34}$ | $\frac{1}{37}$ |
| If $c=\frac{1}{6}$, H = P× .......... | $\frac{9}{14}$ | $\frac{8}{18}$ | $\frac{7}{22}$ | $\frac{6}{26}$ | $\frac{5}{30}$ | $\frac{4}{34}$ | $\frac{3}{38}$ | $\frac{2}{42}$ | $\frac{1}{46}$ |
| If $c=\frac{1}{7}$, H = P× .......... | $\frac{9}{15}$ | $\frac{8}{20}$ | $\frac{7}{25}$ | $\frac{6}{30}$ | $\frac{5}{35}$ | $\frac{4}{40}$ | $\frac{3}{45}$ | $\frac{2}{50}$ | $\frac{1}{55}$ |
| If $c=\frac{1}{9}$, H = P× .......... | $\frac{9}{17}$ | $\frac{8}{24}$ | $\frac{7}{31}$ | $\frac{6}{38}$ | $\frac{5}{45}$ | $\frac{4}{52}$ | $\frac{3}{59}$ | $\frac{2}{66}$ | $\frac{1}{73}$ |
| If $c=\frac{1}{10}$, H = P× .......... | $\frac{9}{18}$ | $\frac{8}{26}$ | $\frac{7}{34}$ | $\frac{6}{42}$ | $\frac{5}{50}$ | $\frac{4}{58}$ | $\frac{3}{66}$ | $\frac{2}{74}$ | $\frac{1}{82}$ |
| If $c=\frac{1}{100}$, H = P× .......... | $\frac{9}{108}$ | $\frac{8}{206}$ | $\frac{7}{304}$ | $\frac{6}{402}$ | $\frac{5}{500}$ | $\frac{4}{598}$ | $\frac{3}{696}$ | $\frac{2}{794}$ | $\frac{1}{892}$ |
| If $c=\frac{1}{1000}$, H = P+ .......... | $\frac{9}{1008}$ | $\frac{8}{2006}$ | $\frac{7}{3004}$ | $\frac{6}{4002}$ | $\frac{5}{5000}$ | $\frac{4}{5998}$ | $\frac{3}{6996}$ | $\frac{2}{7994}$ | $\frac{1}{8992}$ |

OBSERVATIONS ON TABLE V.

This mathematical analysis of the effects of positive segregation and segregate fecundity when coöperating brings distinctly into view several important relations

First. Incomplete forms of segregation, that avail little or nothing in preventing a form from being absorbed in the course of time, become very efficient when strengthened by moderate degrees of mutual sterility. Take, for instance, the line of the table in which $c = \frac{1}{100}$. If 1 in every 100 unions is a cross with some other form, the form will in time be overwhelmed, unless other causes come in to counteract; but here we see that, if segregate fecundity occurs in the ratio of 10 to 9, the pure form becomes 12 times as numerous as the half-breeds; and if in the ratio of 10 to 5, it becomes 100 times as numerous.

Second. Again, if we take the proportional differences between the different terms of the top line opposite $c = \frac{1}{2}$, we shall find them very unlike the differences that appear in the bottom line opposite $c = \frac{1}{1000}$. In the former the first term is 9 times as large as the last; while in the latter the first term is more than 80 times as large as the last. This shows that when segregation is intense, differences in the degree of segregate fecundity produce greater contrasts than the same differences do when the segregation is slight.

Third. A similar distinction is found when we compare the right-hand column with the left-hand column. The smallest term in the former is to the largest term in the same column as 1 to 899, while in the left-hand column the greatest difference is as 1 to 100. This shows that when segregate fecundity is strongly developed, differences in the degrees of segregation produce greater contrasts than the same differences produce when the segregate fecundity is but slightly developed.

Fourth. Once more let us consider the relations to each other of the four terms that stand in the upper left-hand corner of the table. Suppose that of some one variety of a plant species, characterized by pre-potential segregation and segregate fecundity, we have occurring in equal numbers four variations whose relations to other varieties are indicated by the figures given in these four terms, while in their relations to each other they are completely fertile and not segregated. Which variation will leave the greatest number of pure offspring; that is, the greatest number of offspring belonging to the one variety to which the four variations alike belong? Evidently the variations represented by the fraction $\frac{8}{12}$ will have the greatest influence on the following generation. But as the supposed conditions allow of exact computation, let us look at the problem a little closer. If each variation numbers say a thousand individuals, then the number of each that will breed true will be as follows: Of the one represented by—

$\frac{9}{16}$, 526 will breed true and 474 will cross,
$\frac{9}{11}$, 550 will breed true and 450 will cross,
$\frac{8}{16}$, 555.5 will breed true and 444.5 will cross,
$\frac{8}{12}$, 600 will breed true and 400 will cross.

And the next generation of each kind will be as follows: Multiplying the pure parents by 10, and the hybrid parents by 8 or 9, according to the value of $m$, we have those represented by—

$\frac{9}{16}$, pure offspring 5260, hybrids 4266,
$\frac{9}{11}$, pure offspring 5500, hybrids 4050,
$\frac{8}{16}$, pure offspring 5555, hybrids 3556,
$\frac{8}{12}$, pure offspring 6000, hybrids 3200.

There can therefore be no doubt that under such conditions the average pre-potential segregation and segregate fecundity of the next generation wlll be considerably advanced, and so with each successive generation till the average of the pure forms is represented by the fraction $\frac{8}{12}$, and is surrounded by a circle of variations, of which one will be represented by the fraction $\frac{7}{16}$. And from this new point continuous advance will be made toward ever higher and higher grades of segregation and segregate fecundity; though of course the process will be subject to antagonisms and limitations arising from the principles of self-accumulating vigor and self-accumulating adaptation. Let it however be carefully noted that we have in this process the manifestation of a new principle, for it rests not only on self-accumulating positive segregation, but on self-accumulating segregate fecundity.

TABLE VI.—*Formula for Segregation, Segregate Fecundity, and Segregate Vigor, giving the proportion of Half-breeds to Pure-breeds (constructed from Table III, according to rule 3).*

| Pure-breeds. | | Half-breeds. |
|---|---|---|
| A | Initial number. | |
| $A(MV-MVc)$. | 1st generation ..... | $Amvc$. |
| $A(MV-MVc)^2$. | 2nd generation..... | $Amvc(1-2c)mv+Amvc(MV-MVc)$. |
| $A(MV-MVc)^3$. | 3rd generation..... | $Amvc((1-2c)mv)^2+Amvc(MV-MVc)(1-2c)mv+Amac(MV-MVc)^2$. |
| $A(MV-MVc)^4$. | 4th generation..... | $Amvc((1-2c)mv)^3+Amvc(MV-MVc)((1-2c)mv)^2+Amvc(MV-MVc)^2(1-2c)mv+Amvc(MV-MVc)^3$. <br> $=Amvc(MV-MVc)^3\left(\frac{((1-2c)mv)^3}{(MV-MVc)^3}+\frac{((1-2c)mv)^2}{(MV-MVc)^2}+\frac{((1-2c)mv)}{(MV-MVc)}+\frac{(MV-MVc)^3}{(MV-MVc)^3}\right)$. |
| $A(MV-MVc)^{n-1}$ | $n-1$th generation. | |
| $A(MV-MVc)^n$ | $n$th generation..... | $Amvc(MV-MVc)^{n-1}\left(\left(\frac{(1-2c)mv}{MV-MVc}\right)^{n-1}+\ldots+\left(\quad\right)^3+\left(\frac{(1-2c)mv}{MV-MVc}\right)^2+\frac{(1-2c)mv}{MV-MVc}+1\right)$. <br> $n$th generation of Pure breeds $=A(MV-MVc)^{n-1}\times(MV-MVc)$; and therefore $\frac{\text{Half-breeds}}{\text{Pure-breeds}}=\frac{mvc}{MV-MVc}\times\left(1+\frac{(1-2c)mv}{MV-MVc}+\ldots\right)$. |

In the above formula V=vigor of pure-breeds expressed by a fraction that gives the proportion of each generation that grow to maturity and propagate; $v$=the vigor of the half-breeds expressed in the same way.

TABLE VII.—*Formula for Segregation, Segregate Fecundity, and Segregate Vigor, giving the proportion of the Three-quarter-breeds to the Pure-breeds.*

T=the number of Three-quarter-breeds, $m'$=ratio of fertility for the same; $v'$, a fraction giving the proportion of the Three-quarter-breeds that come to maturity. H=the number of Half-breeds. P=the number of Pure-breeds.

Turning to Table I, we find that the Three-quarter-breeds of each generation are the offspring of $\frac{1}{10}$ (or $c$) of the previous generation of Half-breeds who consort with an equal number of Pure-breeds, plus the descendants of previous generations of Three-quarter-breeds in as far as they breed with each other. Commencing our computation with the $n$th generation we know from Table VI, that the previous generation of Pure-breeds=$A\ (MV-MVc)^{n-1}$, and the Half-breeds of the same generation=$A(MV-MVc)^{n-1}\times\frac{H}{P}$; $\frac{H}{P}$ being the ratio in which Half-breed stand to Pure-breeds, which is obtained as shown in Tables IV, V, and VI; and $c$ of this number will consort with an equal number of Pure-breeds, making $A(MV-MVc)^{n-1}\times\frac{H}{P}\ 2c$ parents in the $n-1$th generation, that will produce $m'v'$ times that number of Three-quarter-breed offspring of the $n$th generation that will grow to maturity. Starting

with this number in the $n$th generation, and pursuing the same method as was used in constructing Table III, we obtain the following series:

Three-quarter-breeds—

$$n\text{th generation} = A(MV-MVc)^{n-1}\frac{H}{P}2c\,m'v'.$$

$$(n+1)\text{th generation} = A(MV-MVc)^{n-1}\frac{H}{P}2c\,m'v' \times (1-2c)m'v' + A(MV-MVc)^{n}\frac{H}{P}2c\,m'v'.$$

$$(n+2)\text{th generation} = A(MV-MVc)^{n-1}\frac{H}{P}2c\,m'v'\Big((1-2c)m'v'\Big)^2 + A(MV-MVc)^{n}\frac{H}{P}2c\,m'v' \times \Big((1-2c)m'v'\Big) + A(MV-MVc)^{n+1}\frac{H}{P}2c\,m'v'.$$

$$(n+n)\text{th generation} = A(MV-MVc)^{n-1}\frac{H}{P}2c\,m'v'(MV-MVc)^{n}\left(\left(\frac{(1-2c)m'v'}{MV-MVc}\right)^{n} + \cdots + \left(\frac{(1-2c)m'v'}{MV-MVc}\right)^{2} + \left(\frac{(1-2c)m'v'}{MV-MVc}\right)^{1} + \left(\frac{MV-MVc}{MV-MVc}\right)^{n}\right).$$

In the $(n+n)$th generation, $P = A(MV-MVc)^{n+n}$; and therefore $\frac{T}{P} = \frac{\frac{H}{P}2c\,m'v'}{MV-MVc} \times$

$$\left(1 + \left(\frac{(1-2c)m'v'}{MV-MVc}\right)^{1} + (\quad)^{2} + (\quad) + (\quad)^{n}\right).$$

TABLE VIII.—*Simplified formulas, giving the proportions in which Half-breeds and Three-quarter-breeds stand to Pure-breeds when we have both Segregate Fecundity and Segregate Vigor.*

From Table VI we learn that

$$\frac{H}{P} = \frac{mrc}{MV-MVc} \times \left(1 + \frac{(1-2c)mr}{MV-MVc} + \ldots\right).$$

When the numerator, $(1-2c)mr$, is less than the denominator, $MV-MVc$, the sum of the whole series within the brackets may be obtained in accordance with the formula $S = \frac{a}{1-q}$, in which $S$ = the sum of the series, $a$ = the first term, and $q$ = the constant multiplier.

$$\therefore \frac{H}{P} = \frac{mrc}{MV-MVc} \times \frac{1}{1 - \frac{(1-2c)mr}{MV-MVc}}$$

$$= \frac{mrc}{MV-MVc} \times \frac{MV-MVc}{MV-MVc-mr+2mrc} = \frac{mrc}{MV-mr+(2mr-MV)c}. \quad \ldots \quad (1)$$

Applying the same method to the formula in Table VII, we find that

$$\frac{T}{P} = \frac{H}{P} \times 2 \times \frac{m'r'c}{MV-m'r'+(2m'r'-MV)c}.$$

$$\therefore \frac{T}{P} = \frac{H}{P} \times \frac{2m'r'c}{MV-m'r'+(2m'r'-MV)c}; \quad \ldots \quad (2)$$

and

$$\frac{T}{H} = \frac{2m'r'c}{MV-m'r'+(2m'r'-MV)c}. \quad \ldots \quad (3)$$

If $M=10$, $m=5$, $m'=5$, $V=\frac{1}{9}$, $r=\frac{1}{10}$, $r'=\frac{1}{10}$, $c=\frac{1}{10}$,

then $\frac{H}{P} = \frac{\frac{5}{100}}{\frac{10}{9}-\frac{5}{10}+(\frac{10}{10}-\frac{10}{9})\frac{1}{10}} = \frac{\frac{5}{100}}{\frac{100}{90}-\frac{45}{90}-\frac{1}{90}} = \frac{\frac{5}{100}}{\frac{54}{90}} = \frac{450}{5400} = \frac{9}{108} = \frac{1}{12}$;

and (as $m=m'$, and $r=r'$)

$$\frac{T}{H} = 2\frac{H}{P} = 2\tfrac{1}{12} = \tfrac{1}{6}; \text{ and } \frac{T}{P} = \frac{H}{P} \times \frac{T}{H} = \tfrac{1}{12} \times \tfrac{1}{6} = \tfrac{1}{72}.$$

If $M=10$, $m=10$, $m'=10$, $V=\frac{1}{9}$, $r=\frac{1}{90}$, $r'=\frac{1}{90}$, $c=\frac{1}{10}$,

then $\frac{H}{P} = \frac{\frac{1}{90}}{\frac{10}{9}-\frac{10}{90}+(\frac{20}{90}-\frac{10}{9})\frac{1}{10}} = \frac{\frac{1}{90}}{\frac{100}{90}-\frac{10}{90}+\frac{2}{90}-\frac{10}{90}} = \frac{1}{82}$;

and $\frac{T}{H} = \frac{2}{82} = \frac{1}{41}$; and $\frac{T}{P} = \frac{H}{P} \times \frac{T}{H} = \frac{1}{3362}$.

In this latter case, where the Vigor of Hybrids is $\frac{1}{16}$ that of Pure-breeds, while their Fecundity is equal to that of Pure-breeds, we find $\frac{H}{P}=\frac{1}{32}$, which is the same result as that given in the eighth line of the last column of Table V, where the Fecundity of cross unions and of Hybrids is $\frac{1}{16}$ that of Pure-breeds, while their Vigor is equal.

### THE INFLUENCE OF SEGREGATE VIGOR.

I think we may say we have here come in sight of one form of the still wider fourfold law already mentioned; for on the same principle that segregate fecundity increases when once allied with partial segregation in vigorous forms, segregate vigor must also tend to increase when brought into the same alliance; and I believe it will be found that there is a similar principle tending to the self-accumulation of segregate adaptation.

At the point where they both arise, that is during the period that immediately follows the act of impregnation, it is difficult to distinguish between the two principles, and the mortality of the hybrid embryo before birth, or before it leaves the egg, may be conveniently classed as segregate fecundity.*

Though the two principles are so closely related, it would be a great mistake not to distinguish them; for there is no close correspondence between the degrees in which the two qualities occur in the relations of individuals or varieties; and some cases we find segregate fecundity associated with integrate vigor. The mule, though absolutely sterile, possesses vigor equal, if not superior, to that of either parent. In the record of experiments given by Darwin in "Cross and Self Fertilization in the Vegetable Kingdom" mention is made of certain species in which self-fertilized flowers are more fertile than the cross-fertilized, while the plants produced from the cross seed are the more vigorous; and of other species in which cross-fertilized flowers are by far the most productive, while the plants produced from the crossed seed are neither taller nor heavier than the self-fertilized.† In the same work the common pea (*Pisum sativum*), the common tobacco (*Nicotiana tabacum*), and *Canna Warscewiczi* are shown to be more vigorous when raised from self-fertilized seed than when raised from seed crossed with other individuals of the same strain; but in the case of the tobacco and the pea great increase of vigor is produced by a cross with a slightly different variety, while the fertility is increased but little if any.

But the most interesting of all his experiments as bearing on the subject of segregate vigor, is given in the history of "*The Descendants of the self-fertilized Plant, named* Hero, *which appeared in the Sixth Self-fertilized Generation of* Ipomœa purpurea." "A cross between the children of *Hero* did not give to the grandchildren any advantage over the self-fertilized grandchildren raised from the self-fertilized children." "And,

* See "Origin of Species," 6th edition, p. 249.

† See "Cross and Self-Fertilization," pp. 322–329.

what is far more remarkable, the great-grandchildren, raised by crossing the grandchildren with a fresh stock, had no advantage over either the inter-crossed or the self-fertilized great-grandchildren. It thus appears that *Hero* and its descendants differed in constitution in an extraordinary manner from ordinary plants of the same species." "If we look to the (ordinary) plants of the ninth generation in Table X, we find that the inter-crossed plants (of the same stock) were in height to the self-fertilized as 100 to 79, and in fertility as 100 to 26; whilst the Colchester-crossed plants (raised by crossing with a fresh stock) were in height to the intercrossed as 100 to 78, and in fertility as 100 to 51."* The Colchester-crossed plants were therefore in height to the self-fertilized as 1 to $0.78 \times 0.79$, or as 1000 to 616, and in fertility as 1 to $0.51 \times 0.26$, or as 1000 to 133; while the self-fertilized descendants of *Hero* when crossed with the same fresh stock not only had no advantage over those that had been continuously self-fertilized for nine generations, but, as the details of the experiment show, the advantage was on the side of the plants raised from the self-fertilized seed. The experiment was conducted under conditions decidedly unfavorable for the production of healthy plants; but as it is usually found that the superiority of crosses between varieties is most clearly brought to light when the competitors are subjected to unfavorable circumstances, it seems to furnish even stronger evidence of segregate vigor being occasionally produced in the earliest stages of divergent evolution than would have been furnished if the same degree of superiority in the self-fertilized plants had been obtained under a less severe test. As the case is of unusual interest, I give the details as recorded by Darwin:

"Several flowers on the self-fertilized grandchildren of *Hero* in Table XVI were fertilized with pollen from the same flower; and the seedlings raised from them (great-grandchildren of *Hero*) formed the ninth self-fertilized generation. Several other flowers were crossed with pollen from another grandchild, so that they may be considered as the offspring of brothers and sisters, and the seedlings thus raised may be called the inter-crossed great-grandchildren. And lastly other flowers were fertilized with pollen from a distinct stock, and the seedlings thus raised may be called the Colchester-crossed great-grandchildren. In my anxiety to see what the result would be I unfortunately planted the three lots of seeds (after they had germinated on sand) in the hot-house in the middle of winter, and in consequence of this the seedlings (twenty in number of each kind) became very unhealthy, some growing only a few inches in height, and very few to their proper height. The result therefore can not be fully trusted; and it would be useless to give the measurements in detail. In order to strike as fair an average as possible I first excluded all the plants under 50 inches in height, thus rejecting all the most unhealthy plants. The six self-fertilized thus left were on an average 66.86 inches high, the eight inter-crossed

* "Cross and Self-Fertilization," pp. 47, 60, 61.

plants 63.2 high, and the seven Colchester-crossed 65.37 high; so that there was not much difference between the three sets, the self-fertilized plants having a slight advantage. Nor was there any great difference when only the plants under 36 inches in height were excluded. Nor again when all the plants, however much dwarfed and unhealthy, were included.

"In this latter case the Colchester-crossed gave the lowest average of all; and if these plants had been in any marked manner superior to the other two lots, as from my former experience I fully expected they would have been, I can not but think that some vestige of such superiority would have been evident, nothwithstanding the very unhealthy condition of most of the plants. No advantage, as far as we can judge, was derived from inter-crossing two of the grandchildren of Hero, any more than when two of the children were crossed. It appears, therefore, that Hero and its descendants have varied from the common type, not only in acquiring great power of growth and increased fertility when subjected to self-fertilization, but in not profiting from a cross with a distinct stock; and this latter fact, if trustworthy, is a unique case, as far as I have observed in all my experiments."*

Let us now consider for a moment what must be the result when such a variation occurs in a wild species subject to the ordinary conditions of competition. In the first place, it would gradually prevail over other representatives of the same local stock, both by its more vigorous growth and by its greater fertility, especially in the case of flowers that failed of securing a cross. And afterwards, when it came into competition with the equally adapted variety from which it was partially protected by segregate vigor, it would neither be driven out nor lose its separate existence in a commingled race. It will be observed that we have in such a case local, germinal, and floral segregation, each producing partial effects which are enhanced by the segregate vigor. In order to bring out the relation of these factors to each other, let us assume definite values for each. Let us suppose that $\frac{3}{10}$ of the flowers are self-fertilized, $\frac{3}{10}$ are fertilized with pollen from another flower of the same plant, $\frac{3}{10}$ are fertilized with pollen from other plants of the same new variety, and $\frac{1}{10}$ are fertilized with pollen from the older variety occupying contiguous areas. Therefore the sum of the segregating influences, which is called the "Ratio of pure breeding," and is represented by R in Table II, equals $\frac{9}{10}$; and the "Ratio of cross-breeding," represented by $c$ in all the tables, equals $\frac{1}{10}$. Again, let us suppose that the fertility of the pure breeds is the same as that of the half-breeds, but that the superior vigor of the former is such that any one of the pure seeds has twice as good a chance of germinating, growing to maturity, and producing seeds as any one of the crossed seeds. The general effect on the final result will in that case be the same as if the "Ratio of increase for the pure unions" (which I call M)

* "Cross and self-fertilization in the vegetable kingdom," pp. 50, 61.

equalled 10, while the "Ratio of increase for the cross unions" (which I call $m$) equaled 5. Turning now to Table V, we can easily find the ratio in which the number of pure-breeds will stand to the half-breeds, if the conditions continue long; for in the column in which $m$ equals 5 and in the line marked $c=\frac{1}{10}$ we find $\frac{5}{50}$, which means that the half-breeds will equal the pure-breeds multiplied by $\frac{5}{50}$, or by $\frac{1}{10}$.

### SEGREGATE VIGOR AND SEGREGATE FECUNDITY BETWEEN HUMAN RACES.

My attention has recently been called to the following facts relating to the Japanese and Aino races, who have for many centuries met under circumstances favorable for interfusion without any apparent effect of this kind. I quote from "Memoirs of the Literature College, Imperial University of Japan," No. 1: "The Language, Mythology, and Geographical Nomenclature of Japan viewed in the Light of Aino Studies," by Basil Hall Chamberlain, p. 43:

"With what logic, it may be urged, do you invite us to accept a great extension of the Aino race in early Japan, when it is a physiological fact, vouched for by so high an authority as Dr. Baelz, that there is little or no trace of Aino blood in the Japanese people? In reply to this some would perhaps quote such examples as New England, whence the Indians have vanished, leaving nought behind them but their place-names. In Japan, however, the circumstances are different from those of New England. There has undoubtedly been constant inter-marriage between the conquerors and the native race upon the Aino border. We can infer this from history. Those who have traveled in Yezo know it by personal experience to-day. Nevertheless, these inter-marriages may well consist with the absence of any trace of Aino blood in the population. As a matter of fact, the northern Japanese, in whose veins there should be most Aino blood, are no whit hairier than their compatriots in central and southern Japan. Anyone may convince himself of this by looking at the coolies (almost all Nambu or Tsugaru men) working in the Hakodate streets during the summer months, when little clothing is worn. But the paradox is only on the surface. The fact is that the half-castes die out—a fate which seems, in many quarters of the world, to follow the miscegenation of races of widely divergent physique. That this is the true explanation of the phenomenon was suggested to the present writer's mind by a consideration of the general absence of children in the half-bred Aino families of his acquaintance. Thus, of four brothers in a certain village where he staid, three have died leaving widows without male children and with only one or two little girls between the three. The fourth has children of both sexes; but they suffer from affections of the chest and from rheumatism. Mr. Batchelor, whose opportunities for observation have been unusually great, concurs in considering this explanation as sufficient as it is simple. There are scores of mixed marriages every year. There

are numerous half-breeds born of these marriages. But the second generation is almost barren; and such children as are born—whether it be from two half-bred parents, or from one half-breed parent and a member of either pure race, are generally weakly. In the third or fourth generation the family dies out. It may be added that the half-breeds have a marked tendency to baldness, and that their bodies are much less hairy than those of the genuine Ainos. This fact has doubtless helped to cause the divergence of opinion with regard to Aino hairiness. For the comparatively smooth half-breeds usually speak Aino, dress Aino fashion, and are accounted to be Ainos, so that travellers are likely to be misled, unless constantly on their guard. There seem to be half-breeds in all the villages whither Japanese peddlers and fishermen have penetrated. There have therefore probably at some time or other, been half-breeds in every section of Japan where the two races have come in contact."

If these two races were equal in civilization and in natural adaptation to the environment, or if one race was specially adapted to mountain life and the other to life by the seashore, it seems probable that they might permanently occupy adjoining countries without losing any of their distinctive characteristics. Broca, after careful collation of all the information that could be gathered from the publications of travellers and historians, reaches the conclusion "that alliances between the Anglo-Saxon race and the Australians and Tasmanians are but little prolific; and that the mulattoes sprung from such intercourse are too rare to have enabled us to obtain exact particulars as to their viability and fecundity."* I have no means of knowing whether later investigations in Australia and other parts of the world have thrown fuller light on the mutual fertility or sterility of the more divergent human races, but I am inclined to think that the interest in the subject has declined since Darwin has shown that such data can never afford proof that the different races of man are not descended from common ancestry. There are however signs that a renewed interest in the subject is being awakened through the realization that it has a direct bearing on the theory of the origin of species.

### IMPREGNATIONAL SEGREGATION A CAUSE OF DIVERGENCE IN BOTH ITS EARLIER AND LATER STAGES

As we have already seen, the negative factors† segregate vigor and segregate fecundity would tend to produce extinction if not associated with positive forms of segregation. But in the case of organisms whose fertilizing elements are disributed by wind and water, the qualities that produce these negative forms of segregation are usually accompanied by those that produce pre-potential

* See "Phenomena of Hybridity in the Genus *Homo*." By Paul Broca. English translation, published for the Anthropological Society of London by Longman, Green, Longman, and Roberts (1864). pp. 45–60.

† For a definition of negative segregation see page 309 of this paper.

segregation, which is in an important degree positive. But even prepotential segregation, when produced by mutual incompatibility between a few individuals and a numerous parent stock, depends for its continuance and development on local, germinal, or floral segregation, partially securing the intergeneration of a few that are mutually compatible. On the one hand, impregnational segregation depends on some degree of local, germinal, or floral segregation which is a constant feature in most species; but, on the other hand, not only do these initial forms of positive segregation fail of producing any permanent divergence till associated with impregnational segregation, but the more effective forms of positive segregation, such as industrial, chronal, fertilizational, sexual, and social segregation, often depend on impregnational segregation, inasmuch as the divergence of endowments which produces these depends on impregnational segregation. Moreover, in all such cases, increasing degrees of diversity in the forms of adaptation, and consequently of diversity in the forms of natural selection, must also depend upon these negative factors, which in their turn depend on the weak, initial forms of postive segregation.

Divergent evolution always depends on some degree of positive segregation, but not always on negative segregation. Under a rigorous condition of the former (as for example complete geographical segregation), considerable divergence may result without any sexual incompatibility. Darwin has shown, by careful experiments, that integrate vigor and fecundity is the relation in which the varieties of one species usually stand to each other. This fact does not however prove that the more strongly divergent forms, called species, which are prevented from coalescing by segregate vigor and fecundity, did not acquire some degree of this latter character before any permanent divergence of form was acquired. Their having acquired this segregating characteristic may be the very reason why their forms are now so decidedly different, for without it they would have been swallowed up by the incoming waves of inter-generation. Again, we must remember that forms only moderately divergent are habitually classed as different species if they are separated by segregate vigor and fecundity (that is, by some degree of mutual sterility), unless observation shows that they are of common descent. These two considerations sufficiently explain why the varieties of one species are so seldom reported as mutually infertile. Notwithstanding this, the experiments of Gartner and of Darwin, already referred to at length, seem to show that segregate fecundity and vigor may arise between varieties that spring from one stock. In view of these cases, we must believe that in the formation of some—if not many—species, the decisive event with which permanent divergence of allied forms commences is the intervention of segregate fecundity or vigor between these forms. Positive segregation, in the form of local, germinal, or floral segregation producing only transitory divergencies, always exists between the portions of a species

that has many members, but as it does not directly produce the negative segregation which is, in such cases, the necessary antecedent of permanent divergence, we can not, in accordance with the usage of language, call it *the* cause of the permanent divergence. Moreover, though it may be in accordance with ordinary language to call the negative segregation, which is the immediate antecedent of the permanent divergence, the cause of the same, it will be more correct to call the coincidence of the negative and positive segregations the cause, and still more accurate to say that the whole range of vital activities (when subjected to the limitations of any sexual incompatibility that corresponds in the groups it separates to some previous but ineffectual local, germinal, or floral segregation) will produce permanent divergence.

In many cases not only is the entrance of impregnational segregation the cause of the commencement of permanent divergence, but its continuance is the cause of the continuance of the divergence. The clearest illustration of this is found in the case of plants that are fertilized by pollen that is distributed by the wind. All the higher, as well as the lower, groups of such plants would rapidly coalesce if each grain of pollen was capable of producing fertilization, with equal certainty, promptness, and efficiency, on whatever stigma it might fall. We may also be sure that, with organisms that depend upon water for the distribution of their fertilizing elements, impregnational segregation is an essential factor in the development of higher as well as of lower taxonomic groups.

It is important to observe that, in the cases under consideration, *the inferior fertility or vigor resulting from the crossing* of the incompatible forms is as truly a cause of divergence as *the inferior opportunity for crossing* which from the first existed between the members occupying different localities or between the flowers growing on different trees of the same species. The former has been called negative, and the latter positive, segregation, not for the sake of distinguishing different grades of efficiency, but for the sake of indicating the different methods of operation in the two classes of segregation.

### c) *Institutional segregation.*

Institutional segregation is the reflexive form of rational segregation. It is produced by the rational purposes of man embodied in institutions that prevent free inter-generation between the different parts of the same race.

As the principal object of the present paper is to call attention to the causes of segregation acting independently of effort and contrivance directed by man to that end, it will be sufficient to enumerate some of the more prominent forms under which institutional segregation presents itself, noting that some of these influences come in as supplemental to the laws of segregation already discussed, simply re-

enforcing by artificial barriers the segregations that have their original basis in nature. The chief forms that should be enumerated are national, linguistic, caste, penal, sanitary, and educational segregation; and if we had not already considered industrial segregation in the previous chapter, that might be added.

## CONCLUDING REMARKS.

Besides artificial and institutional segregation, which depend on the rational purpose of man, we have now considered numerous forms of segregation, resting on no less than 18 groups of purely natural causes. Owing to the length of this paper I deem it wise to bring it to a close without discussing the laws that co-operate in intensifying the effects directly produced by the segregative causes already considered. As I have shown in Chapter II, segregation is not simply the independent generation of the different sections of a species, but the independent generation of sections that differ; and though no one will believe that any two sections of a species are ever exactly equivalent, it is evident that the degrees of difference may be greater or less, and that whatever causes a greater difference in two sections that are prevented from intergenerating will also be a cause of increased segregation.

It has been observed that some of the causes enumerated in this and the previous chapter are primarily separative, and that no one of those that are primarily segregative is at any one time segregative in regard to many classes of characters. As several forms of segregation may co-operate in securing a given division of a species and one form is super-imposed upon another the aggregate effect must be incalculably great; but we easily perceive that it may be indefinitely enhanced by causes producing increased divergence in the segregated branches. The causes which produce monotypic evolution when associated with inter-generation must be equally effective in producing polytipic evolution when associated with se-generation, whether in its separative or segregative forms. But the discussion of intensive segregation must be reserved for another occasion.

Believing that the study of cumulative segregation in its relations to the other factors of evolution will throw light on the origin of species far beyond what I have been able to elicit, I trust the subject will secure the attention of those who enjoy better opportunities than I do for carrying forward such investigations.

## *APPENDIX.*

### CLASSIFIED TABLE OF FORMS OF SEGREGATION.

**A.**

Environal segregation.
- (*a*) Industrial segregation.
  - Sustentational.
  - Defensive.
  - Nidificational.
- (*b*) Chronal segregation.
  - Cyclical.
  - Seasonal.
- (*c*) Spatial segregation.
  - Geographical. / Local. — Migrational. / Transportational. / Geological.
- (*d*) Fertilizational segregation.
- (*e*) Artificial segregation.

**B.**

Reflexive segregation.
- (*a*) Conjunctional segregation.
  - Social.
  - Sexual.
  - Germinal.
  - Floral.
- (*b*) Impregnational segregation.
  - Segregate size.
  - Segregate structure.
  - Prepotential segregation.
  - Segregate fecundity.
  - Segregate vigor.
- (*c*) Institutional segregation.

**C.**

Intensive segregation.
- (*a*) Assimilational intension.
- (*b*) Stimulational intension.
- (*c*) Suetudinal intension.
- (*d*) Correlated intension.
- (*e*) Integrational intension.
- (*f*) Selectional intension.
- (*g*) Fecundal intension.
- (*h*) Eliminational intensional.

# THE STRUGGLE FOR LIFE IN THE FOREST.*

By James Rodway.

Guiana is, above everything else, famous for its varied and rampant forms of vegetable life. It is a country of magnificent timber trees, elegant palms, wonderful creeping, climbing, and scrambling vines, enormous arums, and stately grasses. All of these seem conscious that they have to struggle for existence and that the fittest only will survive. Here we have no forest of one species—in which there appears to be something like combination, but every plant is an individual, and as such strives with all its might to get ahead of its neighbor, no matter how. Its whole aim and end is to obtain a share of the bright sunlight which is so plenteously bestowed, but nevertheless is so hard to get at. As long as the individual succeeds it does not care what becomes of the others; "everyone for himself and the sunlight for him who outstrips the others" appears to be their motto.

Myriads of seeds are distributed in every direction; some are eaten by birds, others by quadrupeds and monkeys, while the vast majority are washed away by floods or die in the first stage of babyhood. A hundred may germinate under one tree, but what poor, puny things they are! They try their best to raise themselves toward the light above their heads, but without a share of that light they have no strength. Their seed leaves are almost colorless, while their stems are so fragile that they often break off by their own weight. One by one they fall and die. Here and there however, in some place where a few rays of light have succeeded in penetrating the canopy of foliage, one of them becomes strong enough to get over its first difficulties. Then it uses up all its strength to push its way up and up until it arrives at the top. It does not waste its energy by spreading in any way, either in the stem or by branching, but straight and thin as a walking stick at last forces its way into the sunlight. Now comes a transformation; like a giant forcing his way through a crowd it pushes out a branch in this direction and another in that until it succeeds in elbowing itself into a good place.

Except at night there is no rest in the tropical forest. The struggle goes on all through the year, being perhaps only a little less in the dry season. No nice winter's sleep is possible. Man and the higher ani-

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* From "*Timehri,*" *Journal of the Royal Agricultural and Commercial Society of British Guiana.* June, 1891; vol. v (new series), pp. 13–33.

mals may take things easy, but not so the trees. In the great cities of Europe men have to carry on just such a struggle, but plants in temperate climates jog along quietly; here the case is reversed. From dawn to sunset trees are hard at work—you can almost see some of them growing—and as may naturally be supposed, they must have a little rest at night. The tree is thoroughly exhausted; its branches lose their stiffness, while the leaves droop and fold themselves together. Unlike those of temperate climates, the trees of the tropics all, more or less, show these signs of exhaustion toward sunset.

Forest trees have not only to contend with each other,—this is a fair fight where if not equally matched they are nearly so,—but the struggle must be carried on against interlopers of various kinds. Creeping, twining, and scrambling vines are determined somehow or other to get a share of the sunlight. "There is plenty of room at the the top," but they have to get there. Without light they are like the young trees, poor, sickly, washed-out things, hardly able to to raise themselves even with the aid of the stems of trees or other climbers like themselves. Some few do succeed, however, one way or another—one species of Bignonia by means of veritable claws—and when they get to the top, how they do revenge themselves on the forest trees which have stood in their light. We can fancy one of them saying, "Now, I am going to smother you." And it does so in many cases. It branches out here, there, and everywhere, spreading its leaves upon those of its support, until eventually a wealth of brilliant flowers open out, eclipsing those of the trees altogether. As its branches extend the stem swells and hardens until it looks like a great hempen cable, which, if it happens to be a twiner, constricts its support in serpent-like folds until perhaps the tree is strangled to death. But this does not matter, for by that time the rampant monster has spread itself over a dozen giants of the forest where it revels in the sunlight and seems to crow over its victory.

Perhaps the most insidious enemy against which the forest tree has to contend is the class of stranglers such as clusias and figs. Birds eat the fruit of these horrible plants, and deposit the seeds in the topmost forks of some forest giant, where they germinate. One of these succeeds in getting ahead, and, as its leaves open, it extends a number of aërial roots down the trunk of the tree until they reach the earth. There they go, crawling down, and like very long worms, apparently quite harmless, clinging to the bark, but seeming otherwise entirely wanting in either ability or desire to injure. Now the strangler has gained its footing and begins to feel its power. The aërial roots expand laterally until they actually run into each other and cover the trunk. We can almost fancy the magnificent forest tree protesting strongly, as, octopus-like, the clusia begins to compress and strangle it. It may protest as much as it likes, but that makes no difference; the clusia grows stronger and stronger, until by and by, as the strangler opens its magnificent waxy flowers to the sun and glories in its conquest, the poor, unfortu-

nate victim droops and dies. Then the trunk becomes diseased, wood ants begin their work, and finally nothing is left but the hollow cylinder of the strangler.

There is yet another foe to the giant of the forest, the parasite or bloodsucker, the leech of the vegetable kingdom. Like the leech, it is not very large in comparison with its victim, but that does not matter, as it makes up in numbers what it lacks in size. These plants, called bird vines (*Loranthaceæ*), are, like the stranglers, distributed by birds. The seeds are covered with glutinous pulp, which, when they are dropped by birds, enables them to adhere to the branches of the trees. Here they sprout, and with their young leaves, produce aërial roots, covered with suckers, which run along and insinuate themselves into the cracks of the bark, continually nourishing themselves on the life-blood of their victims. As the loranth extends itself, it seems to revel in the mischief it is producing, looking bright and happy in contrast with its miserable victim, whose limbs begin to wither and fall, until ultimately the branch becomes dry and brittle, when perhaps some day it breaks off by its own weight and comes to the ground, bringing its murderer with it. Sometimes the whole tree will be covered with parasites and ultimately succumb to the continual drain, but more often it survives in a most miserable state of weakness, being hardly able to produce flowers, much less fruit. Like a man suffering under a chronic disease, it drags along its melancholy existence until all its branches wither, when the parasites, having nothing to live on, suffer a just retribution. However, there are always plenty of others to keep up the fight, as the species are very numerous, while the seeds germinate by thousands.

Although there is a scarcity of the larger animals in the forest, this is compensated by the wealth and variety of the insect world. Ants are present in myriads, some of them making sad havoc on the foliage and adding to the numerous foes against which the forest giant has to contend. Then, there is the great army of wood ants, or termites, which are the scavengers. When a tree is elbowed, smothered, strangled, or sucked to death, the wood ants are ever in readiness to dispose of its remains. However hard the timber may be, it is not too tough for these insignificant creatures. To look at, they appear the weakest of all insects. Unable to stand even the subdued light of the forest, having to build covered tunnels so as to be always in darkness, they are nevertheless able in a comparatively short time to make a fallen trunk as fragile as an eggshell. In wandering through the forest you come upon an enormous trunk lying across your path. It is too large to step over, so you put your foot upon it, when, with a crunch, crunch, the apparently hard timber crumbles like a mummy, while the wood ants are scattering in every direction to get under cover. In the larval state the insect world is also the sworn foe of the tree. The elegant palm has its canker at the heart in the shape of the borer beetle. These

princes of the vegetable kingdom are very tender; a single larva will kill the strongest of them. There they stand, like kings deprived of their crowns, until the inevitable scavengers come forward and crumble them into mold.

In the great struggle for light, which means life in the forest, there is no place for small herbaceous plants. Such little beauties as daisies and primroses could find no sunny banks or fields to bask in. The ground is strewn with dead leaves and withered petals, which have fallen from the canopy above, and sometimes you pick up a flower or seed and wonder which tree it came from. You look up and try to identify the foliage of some particular tree, but they are so intermingled that this is almost impossible. There is hardly anything to be seen in the dense forest save an interminable jumble of trunks and bush ropes. However, flowers are not entirely absent. Scattered here and there may be found a few leafless root parasites. One orchid, the *Wullschlegelia aphylla*, is able to exist in the half-light, together with three species of *Voyria*. Except one of the latter, which is like a miniature yellow crocus, these plants are particularly delicate, poor, pale, sickly looking creatures, that seem ready to fall to pieces by their own weight, although they are only 2 or 3 inches high.

However, herbaceous plants are not wanting in the forest. Let us single out a giant Mora, if we can, and use a glass, when we shall see that its limbs are covered with small plants, which may be recognized as orchids and bromelias. Far above our heads are the representatives of Shakespeare's "long purples" and the other temperate orchids which decorate the English meadows. There they sit, 100 to 150 feet above our heads, "born to blush unseen," as far as the human eye is concerned. Nevertheless they live, and perhaps enjoy life, doing their work, and doing it admirably. They do not elbow their neighbors, nor do they smother, strangle, or suck them, but simply make use of the topmost branches of the forest giants as resting places. The orchid grasps its support in a loving manner, holding it tightly, but not like the parasite, to get fat at its expense. No, the orchid has succeeded in making itself almost independent. It is satisfied with a little light; so there is no necessity for interfering with its host. Having, as it were, succeeded in getting out of the turmoil of the fight, it decorates the brawny limbs of the forest giant with its brilliant flowers, and invites the bees and butterflies to come to its nuptials.

Although it apparently takes things very easy, the orchid is by no means idle, while its position to-day represents the outcome of generations of steady work. Having no connection with the soil, it has to gather its food from the air, rain, and dew, and not only to collect, but also to store it. Although rains are frequent enough, still there are dry seasons, when, under the tropical heat, a plant in such a position must wither and die unless some provision were made for these contingencies. Like the plants of the desert, the orchid stores its food in

anticipation of a drought, but every family, and almost every species, does this in a different manner. Some, like *Oncidium Lanceanum*, lay up their store in thick, leathery leaves, so that they can enjoy plenty of sunlight without injury. Others, like the *Cattleya*, have thick leaves and swollen stems, which latter is one of the forms of the pseudo bulb, and is peculiar to the orchid family. Where the leaves are thin the pseudo bulbs are often very large, so that if every leaf should be dried up the plant still retains its vitality. In some cases the store of food is laid up in cylindrical leaves, some resembling porcupine's quills, others like yard lengths of thick twine; in others, there is a plump, fleshy stem which answers the same purpose. A few species have no leaves or pseudo bulbs. In such cases their aërial roots perform all the functions of both.

The *Bromeliaceæ*, wild pines as they are called, have chosen an entirely different manner of storing water against a drought. Folding the bases of their leaves together, and tightly overlapping one upon another, a cup is formed, which retains a store of water for several weeks. Every leaf being a natural gutter leading to this reservoir, the plant succeeds in gathering a little water with every shower, so that it is hardly ever actually dry. Taking advantage of this, a species of *Utricularia*, a strictly aquatic plant, has succeeded in locating itself in these little pools, where it luxuriates far above its swamp-dwelling cousins. Not satisfied with this wonderful contrivance, the Bromelia has also developed a peculiar texture of leaf, almost as tough as horn, but at the same time quite flexible, which enables it to stand such a strong heat and glare as would cripple the more delicate orchid.

Leaving the dense forest, in which only winged creatures can well observe the struggle for life, we come across a river or creek, which, if it is wide enough, breaks the continuity, and allows a streak of sunlight to penetrate. If, on the contrary, the creek be only a narrow one, the forest trees meet overhead, or we paddle our canoe under their trunks and branches, which lean over and almost choke the passage. Where the river is broad the forest slopes down to it, looking at a distance as if there were a high embankment when actually the shore is quite flat for a long distance behind. Here the struggle for life can be fully appreciated, as the vegetation is nearer the eye. All along the banks, without a single break, shrubs and low trees are densely packed together, each trying to find room for itself at the expense of its neighbor. They take up every inch of available space, extending their branches as far as possible over the stream, while the creeping and scrambling vines take advantage of this to spread themselves over the whole face of the embankment of foliage, festooning it with their gay flowers and revelling in the fact that they have succeeded in "coming over" their supporters. Sometimes retribution overtakes them, as they make the shrub or tree so top-heavy that, when a flood comes, the roots are loosened and the swift current tears away the whole mass,

leaving the remains of the lately crowing smotherer bruised, torn, and bleeding.

The elbowing which goes on here differs from that in the "high woods" in the fact that, the struggle being so much the greater, the army of combatants has put on armor. There are no weak, soft creatures here. Almost as soon as the seedlings grow they assume their weapons. Cover a man from head to foot with needles all pointing outward, and set him to elbow himself through a crowd, and you have something like what is actually the fact with a genus of comparatively low palms (*Bactris*). The stems are densely clothed with needle-like spines, while the ribs of the fronds have the same aggressive spikes, all seeming to say defiantly "*Noli me tangere!*" Not content with a single stem, these palms grow in clumps, every new sucker taking its place beyond the others and pushing its weaker neighbors farther out of the way. Most of the low shrubs have stiff and rigid branches, which of themselves form a protection, but not content with this, they often have short, stiff thorns, ready to tear both the leaves and stems of any young plant which tries to force its way through them. Having to contend against such strong opponents, the climbers put on their armor as well. The *Desmoncus* covers its stem with spines, and insinuates its young fronds through some little gap toward the light. Step by step it ascends, the fronds opening one by one, each provided with a most formidable arrow-head having a dozen pairs of barbs, which effectually hold up the weak trailing stem. These barbs are most dangerous weapons of offense to boatmen coming swiftly down the streams, as they hang over as if fishing for anything that comes in their way.

Beyond the line of bushes, and actually in the water, grows the tree-like Mocca-Mocca (*Montrichardia arborescens*), a curious species of aroid which has succeeded in developing itself to a wonderful size. In its young state it is provided with spines, so as to be able to push its way, but as it grows upward these are no longer necessary, and are therefore not found on the upper part of the stem. When the water is shallow they form an impenetrable phalanx of several yards deep all along the shore, their stems being often 20 feet high and packed as closely together as possible.

It might be supposed that the grasses other than bamboos would be entirely absent from the forest region, but such is not the case. One species, *Panicum elephantipes*, has succeeded in getting over the difficulties by taking its place as a water plant. Being provided with large creeping hollow stems, it anchors itself to the branch of some tree that meets the water, and from this point extends outward and along the shore. Growing very quickly, it often covers the surface for some distance from the line of mocca-moccas, and might prove a formidable obstruction, did not the river swell at intervals and carry off large masses, like floating islands, down to the sea.

Beyond the fringe of rampant vegetation nothing can be seen from

the river, but by pushing aside the branches and creepers, so as to get behind the veil, orchids may be seen growing luxuriantly in great numbers. Here live those species that delight in plenty of moisture, and that can not endure the drier atmosphere which is met with in the "high woods." This is the home of *Zygopetalon rostratum*, which is enabled to flourish and produce its beautiful white flowers in more gloomy recesses than most of the others. It has developed a creeping habit, by which it seems to derive benefit, being able by this means to grow upward on a branch as the tree extends itself. When this species is plentiful it forms quite a pretty decoration to the rugged branches.

The places where orchids are seen to advantage are not however on the banks of the great rivers, but rather on those that are wide enough to allow a moderate quantity of light to penetrate. Not having sufficient sun-light to produce rampant vegetation, such places are very congenial to a great number of species. High above the water rise the giant moras and other immense timber trees, while here and there a great trunk leans across the creek, its upper surface decorated with creeping ferns, peperomias, and the smaller species of orchids, such as *Pleurothallis* and *Dichæa*. In some of the larger forks grow immense masses of *Oncidium altissimum*, often 3 or 4 feet across, their elegant flower stems being 10 or 12 feet high, hanging or curving gracefully over and loaded with hundreds of pretty yellow flowers. Brassias are also very common, while here and there *Stanhopea eburnea* perfumes the air with its large ivory-white pendulous blossoms. As the creek twists and turns about a new vista is opened at intervals, every short reach, from the different degree of light, showing some diversity in its forms of vegetation. Now, as the creek narrows, the canoe is paddled through a gloomy cavern almost as dark as night, from which the exit appears at a distance like the termination of a tunnel. Then comes a wide bay where the sun shines in all its brilliancy. Here a mass of vegetation chokes the passage, and the cutlass has to be used freely, while a little farther a forest tree has fallen right across the stream, giving perhaps an hour's work with the ax before the canoe can be pushed through, hauled over, or drawn under.

On leaning trunks or projecting branches the catasetums are generally plentiful. There are several species, which live under entirely different conditions, and taken altogether, this genus is perhaps the best example of adaptation to circumstances in the orchid family. On the borders of the swamps, where only the eta palm will grow, *Catasetum longifolium* finds a congenial home among its lower fronds. There the orchid hangs downward and waves its long grass-like leaves in the wind. *Catasetum discolor*, as a contrast, has come down to the ground, and on the sand reef, where the forest trees find it hard to live, this species revels in the poorest soil. Being provided with large pseudo bulbs, the Catasetum endures the change of seasons without injury. Although its leaves are generally thin and are liable to be dried up

during a drought, this does not injure it, as the reservoir of food enables it to wait patiently and even flower under such conditions as might be fatal to many other orchids. As if this were not enough, several species have developed a faculty which is almost unique in plants, although well known in the case of bees, that of producing male or female according to circumstances. In the case of *Catasetum tridentatum* there are three distinct shapes of flowers, which differ so much from each other that, until Schomburgk found them growing on the same plant, they were described not only as separate species, but even different genera. The male was known as *Myanthus barbatus*, the female as *Monachanthus viridis*, while the third form, which appears to be hermaphrodite, went by what is now the name of the species, *Catasetum tridentatum*. When this plant has plenty of food it produces a spike of female or hermaphrodite flowers, which are thick and fleshy, resembling in shape an old-fashioned woman's cap or sunbonnet. These flowers and their attendant capsules require a special effort, and can only be satisfactorily produced when the plant is in good condition. During a drought, when the plant is half starved, it would be unable to support such a strain, therefore a few lighter and more elegant male flowers are produced, and as there will always be some stronger plants to produce those of the opposite sex the work of the weaker is not lost.

If one passes under one of these plants when in flower, a swarm of yellow and black bumblebees (*Eulema dimidiata*) are seen hovering in its neighborhood and flying from flower to flower. Except in this locality not a single bee is to be seen, and perhaps a collector might search for miles without finding a specimen. But when the Catasetum opens, whether it is hidden in the fork of a tree, perched far up among the foliage of the eta, or on sand thrown up from a charcoal pit, the insect is sure to find it out. The flowers are not generally brilliant or showy, neither have they, like the Stanhopeas, any strong perfumes, but nevertheless the bees discover them at once. Even in Georgetown, where many orchids do not find their fertilizing agents, and consequently remain barren, no sooner does the spike of flowers open than the bees swarm round it. However it may be obstructed by foliage or hidden in some out-of-the-way corner, the buzzing is heard in the early morning, telling anyone who has his eyes open that a Catasetum is flowering. Having succeeded in attracting the bee from a distance in some unaccountable way, a feast is provided in the shape of a little reservoir of nectar, to procure a sip of which the bee has to bring its head in contact with a pair of incurved antennæ, one of which is very sensitive. Immediately on touching this the cover of the little case containing the pollen masses flies off, and, like a skip jack, these spring out, when, by means of a sticky disk with which they are provided, they adhere to the back of the insect and are carried to another flower. Here the pollen masses come in contact with the stigma and the flower is fertilized.

Hanging from a creeper or branch may be seen here and there an oval, bag-like mass of aërial roots, something like one of the nests of the troupials so common on the silk cotton tree, above which are the pseudo bulbs and leaves of that wonderful orchid, the Coryanthes. After throwing out two or three roots to attach itself to its support, it develops an interlacing network all round, in a way almost peculiar to the genus. At first sight it would be hard to say what purpose could be served by such a contrivance, but strike or shake the plant and it will be seen that it is nothing less than a veritable ant's nest. The orchid is, like other plants, subject to the attacks of many foes such as cockroaches and larvæ, which are particularly fond of the aërial roots. To protect itself against these, the Coryanthes has chosen to provide a comfortable nest, wherein a garrison of carnivorous ants find shelter, they, in return for the accommodation, being ready to come out and fight at the first alarm of an enemy. Other orchids which live in the tree tops are not so subject to crawling insects as those nearer the ground, and for that reason it appears that they have never seen the necessity for this special protection. *Epidendron* (*Diacrium*) *bicornutum* has obviously felt this need, and set to work in its own way to accommodate a garrison. Being provided with long, cylindrical pseudo-bulbs, it has left these hollow, and for a doorway, allowed the shell to split for about a quarter of an inch at the base. In these well-protected homes the ants live and thrive, and in return for their lodging, like those of the Coryanthes, are a standing terror to evil doers. Other orchids, such as *Gongora*, provide a half-shelter for ants, but their efforts in that way are of little importance as compared with Coryanthes and Diacrium.

Having provided a guard against crawling vermin, the Coryanthes proceeds to develop a most wonderful flower, in which every part is obviously formed to attract a particular insect. The majority of insect-fertilized flowers are grateful for the visits of either bees, butterflies, or flies, but not so the Coryanthes. It has laid itself out only to catch and utilize, without hurting it, a beautiful metallic green bee (*Euglossa aurata*). From the base of one of its pseudo bulbs, a long flower stem is produced, which pushes itself straight downwards. Upon this it hangs a number of beautiful cups, into each of which a liquid drips from two horn-like processes in the upper part of the flower. Take a china teacup with a spreading mouth, hang some little flags over the handle, and stick a model of the figurehead of a Polynesian canoe opposite, and you have something like one of them, as it opens itself in the early morning from a bud resembling the swathing of a Chinese lady's foot. The species vary in color and markings, being generally whitish or yellow, blotched and spotted with crimson. Their odor, as judged by our standard, is not pleasant, but nevertheless it is very attractive to the bees, which immediately on their opening swarm round in great numbers. Flying toward the flower, as a moth to a candle, the bee falls

into the liquid which covers the bottom, and wetting its wings, is unable to use them. Look into the cup and you will see a dozen bees swimming round and round, or vainly trying to climb the slippery sides, and if it is the second day after opening, one or two may be seen drowned. It was never the intention of the flower, however, that their lives should be sacrificed, but on the contrary, that they should escape, and in doing so perform the office for which the whole contrivance has been arranged. Under the flags, where the column comes near but does not actually touch the cup, is a narrow opening, through which the bee can push its way out. In doing this it has to use sufficient force to widen the gap, which opens like a spring door, when it comes in contact with the pollen case, ruptures it, and carries off the male organ on its back. Not being able to fly, there is nothing to be done but to crawl over the flower spike, where, heedless of its former trouble, it soon finds itself inside another flower. In making its way out, the pollen masses are rubbed on the stigma, and the ovary fertilized, after which it may carry out the pollen masses of this flower in turn to fertilize another. . . .

Another side of the struggle for life is exemplified on the sand reefs. Extending for miles, large expanses of white ridges vary the monotony of dense forest and stream. Here and there, between clumps of low bushes, the open space glares with reflected light and heat, while the sand itself is so hot that the barefooted Indian is obliged to peel two pieces of bark to protect the soles of his feet against it. Without such an excessive rainfall as that of Guiana, these reefs would be quite barren, but under the circumstances, the hardier shrubs and a few trees manage to exist. Where forest trees have succeeded in obtaining a footing they push their roots far down below the surface, where the sand is moist and cool, but finding little food, they naturally grow much slower and are more hardy than the same species in the dense forest. For this reason timber from such places is always highly valued, as being free from sap. Here it is no longer a fight with each other, but a hard struggle for bare existence. Everything is arid and dry, the shrubs being strong and sturdy, though small, while the few herbaceous plants have leaves especially fitted to their surroundings. Try to dig up one of these and you may scrape away for many feet before you get beyond the tap root. Here, in contrast with the "high wood," annuals are seen during the rainy season. Not having been able to develop any other special provision, they flower and die, leaving their seeds to germinate after the drought is over. Orchids abound everywhere upon the low shrubs, while several genera have succeeded in accommodating themselves to the sand itself. Here is a *Cyrtopodium* with a magnificent panicle of yellow flowers, but what a fine pseudo bulb is this! Three to four feet long, and thick and fleshy, it contains a store of food against all contingencies. Unlike its relations of

the tree tops, it revels in the glare, only partially screening itself beside the bushes.

There is a certain amount of uniformity in the "high woods," notwithstanding that two trees of the same species are hardly ever seen together. The conditions being the same, and there being no room for developing many special peculiarities, the result to an ordinary traveller is rather monotonous. The sand reefs, on the contrary, show a fertility of invention. Here, some kinds of plants entirely alter their character with their habitat. A fern (*Schizæa*), instead of showing the delicacy of form and texture common to the order, has changed itself into a wiry grass-like creature, without beauty or comeliness. Lichens and mosses take advantage of the slight screen of the clumps of bushes, and grow on the sand as well as on the branches. Climbers run along the sand, while the demon clusias flourish without strangling their neighbors. Plants whose relatives are forest giants dwindle here to little dwarf shrubs of a few inches high, with small leaves densely covered with hair or down to collect the dew which falls so plenteously in the dry seasons.

Much more could be said on the various aspects of this great struggle. Every species, and even every individual, is worthy of attention. It would almost seem as if thousands of species would fall and become extinct, and that such has been the case there can be no doubt. Nevertheless, there are so many provisions against this, that on the other hand, we see that such a thing is comparatively rare. Opposed to the thousand chances against the individual, nature has provided a thousand and one in its favor. A tree with a multitude of flowers will produce one or two seeds to each, while an orchid, with only a few, often numbers its seeds by tens of thousands. Some trees have fruits which are food for beasts, birds, and fishes, but with all this there will always be a few left to produce others of the same species.

# SOME DIFFICULTIES IN THE LIFE OF AQUATIC INSECTS.*

By Prof. L. C. MIALL.

We understand insects to be animals of small size, furnished with a hard skin and six legs, breathing by branched air tubes, and commonly provided in the adult condition with wings. The animals thus organized are pre-eminently a dominant group, as is shown by the vast number of the species and individuals, their universal distribution, and their various habitat.

The insect type, like some fruitful inventions of man—paper or lithography, for instance—has proved so successful that it has been found profitable to adapt it to countless distinct purposes. I propose to consider one only of its infinitely varied adaptations, viz, its adaptation to aquatic life.

There are insects which run upon the earth, insects which fly in the air, and insects which swim in the water. The same might be said of three other classes of animals, the three highest, viz, mammals, birds, and reptiles. But insects surpass all other classes of animals in the variety of their modes of existence. Owing to their small size and hard skin, they can burrow into the earth, into the wood of trees, or into the bodies of other animals. There are some insects which can live in the water, not as the mammal, bird, or reptile does, coming up from time to time to breathe, but constantly immersed, like a fish. This is the more remarkable because insects are, as a class, air-breathers. Air tubes or tracheæ, branching tubes, whose walls are stiffened by spiral threads, supply all the tissues of the body with air. That such an animal should be hatched in water and live almost the whole of its life immersed, a thing which actually happens to many insects, is a matter for surprise, and implies many modifications of structure, affecting all parts of the body.

The adaptation of insects to aquatic conditions seems to have been brought about at different times, and for a variety of distinct purposes. Many dipterous larvæ burrow in the earth. Some of these frequent the damp earth in the neighborhood of streams. Others are found in earth so soaked with water that it might almost be called mud, though

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they breathe by occasionally taking in atmospheric air. In yet more specialized members of the same order we find that the larva inhabits the mud at the bottom of the stream, and depends for its respiration entirely upon oxygen dissolved in the water. The motive is usually that the larva may get access to the decaying vegetable matter found in slow streams, but some of these larvæ have carniverous propensities.

Other insects merely dive into the water, coming up from time to time to breathe, or skate upon the surface.

Nearly every order of insects contains aquatic forms, and the total number of such forms is very large. I believe that all are modifications of terrestrial types, and it is probable that members of different families have often betaken themselves to the water independently of one another.

The difficulties which aquatic insects have to encounter begin with the egg. It is in most cases convenient that the egg should be laid in water, though this is not indispensable, and the winged, air-breathing fly is as a rule ill fitted for entering water. Some insect eggs hatch if they are merely scattered, like grains of sand, over the bottom of a stream, but others must be laid at the surface of the water, where they can gain a sufficient supply of oxygen. If the water is stagnant it will suffice if the eggs are buoyant, like those which compose the egg raft of the gnat, but this plan would hardly answer in running streams, which would carry light, floating eggs to great distances, or even sweep them out to sea. Moreover, floating eggs are exposed to the attacks of hungry creatures of various kinds, such as birds or predatory insect larvæ. These difficulties have been met in the cases of a number of insects by laying the eggs in chains or strings, and mooring them at the surface of the water. The eggs are invested by a gelatinous envelope, which swells out the moment it reaches the water into an abundant, transparent mucilage. This mucilage answers more than one purpose. In the first place it makes the eggs so slippery that birds or insects can not grasp them. It also spaces the eggs, and enables each to get its fair share of air and sunlight. The gelatinous substance appears to possess some antiseptic property, which prevents water moles from attacking the eggs; for, long after the eggs have hatched out, the transparent envelope remains unchanged. The eggs of the frog, which are laid in the stagnant water of ditches or ponds, float free at the surface, and do not require to be moored. The eggs of many snails are laid in the form of an adhesive band, which holds firmly to the stem or leaf of an aquatic plant. Some insects, too, lay their eggs in the form of an adhesive band. In other cases the egg chain is moored to the bank by a slender cord.

The common two-winged fly, Chironomus, lays its eggs in transparent cylindrical ropes, which float on the surface of the water. During the summer months these egg ropes, which are nearly an

inch in length, may readily be found on the edges of a stone fountain in a garden, or in a water trough by the side of the road. The eggs are arranged upon the outside of the rope in loops, which bend to right and left alternately, forming sinuous lines upon the surface. Each egg rope is moored to the bank by a thread, which passes through the middle of the rope in a series of loops, and then returns in as many reversed and overlapping loops, so as to give the appearance of a lock stitch. The thread is so tough that it can be drawn out straight with a needle without breaking. If the egg rope is dipped into boiling water the threads become apparent, but in the natural state they are invisible, owing to their transparency. The mucilage is held together by the threads inter-woven with the mucilage. The loops can be straightened without injury until the length of the rope is almost doubled. If stretched beyond this point the threads become strained and do not recover their original shape when released. By means of these threads, firmly inter-woven with the mucilage of the egg rope, the whole mass of many hundreds of eggs is firmly moored, yet so moored that it floats without strain, and rises or falls with the stream. The eggs get all the sun and air which they require, and neither predatory insects, nor birds, nor water molds, nor rushing currents of water, can injure them.

The eggs of the caddis-fly are laid in larger ropes, which, in some species, are very beautiful objects, owing to the grass-green color of the eggs. The egg raft of the gnat, which has often been described, is well suited to flotation in stagnant water, and is freely exposed to the air, a point of unusual importance in the case of an insect which in all stages of growth seems to need the most efficient means of respiration, and whose eggs are usually laid in water of very doubtful purity. The lower or submerged end of each egg opens by a lid, and through this opening the larva at length escapes.

The eggs of water-haunting insects are in many ways particularly well suited for the study of development. The eggs of Chironomus, for instance, can always be procured during the summer months. They are so transparent as to admit of examination under high powers of the microscope as living objects, and as they require no sort of preparation, they may be replaced in the water after each examination to continue their development. This saves all trouble in determining the succession of the different stages, a point which usually presents difficulties to the embryologist. The whole development of the egg of Chironomus is completed in a few days (three to six, according to temperature), and it is therefore an easy matter to follow the process throughout with the help of three or four chains of eggs.

When the larvæ are hatched and escape into the water, new difficulties arise. Some have to seek their food at the surface of the water, and must yet be always immersed, others live upon food which is only to be found in rapid streams, and these run serious risk of being swept

away by the rush of water. All need at least a moderate supply of oxygen, which has either to be drawn from the air at the surface, or extracted from the water by special organs. The difficulty of breathing is of course greatly increased when the larva seeks its food at the bottom of foul streams, as is the case with certain Diptera. The larva of Chironomus, for example, feeds upon vegetable matter, often in a state of decay, which is obtained from the mud at the bottom of slow streams, and in this mud the larva makes burrows for itself, cementing together all sorts of materials by the secretion of its salivary glands drawn out into fine silken threads. The burrows in which the larva lives furnish an important defense against fishes and other enemies, but they still further increase the difficulty of procuring a supply of air. Hence, the larva frequently quits its burrow, especially by night, and swims towards the surface. At these times it loops its body to and fro with a kind of lashing movement, and is thus enabled to advance and rise in the water. From the well-aërated water at the surface of the stream it procures a free supply of oxygen, which becomes dissolved in the abundant blood of the larva. Four delicate tubes filled with blood, which are carried upon the last segment of the body, are believed to be especially intended for the taking up of dissolved oxygen. The tracheal system is rudimentary and completely closed, and hence gaseous air can not be taken into the body. The dissolved oxygen, procured with much exertion and some risk, must be stored up within the body of the larva, and used with the greatest economy. It is apparently for this reason that the larva of Chironomus contains a blood-red pigment, which is identical with the hæmoglobin of vertebrate animals. The hæmoglobin acts in the Chironomus larva, as it does in our own bodies, as oxygen-carrier, readily taking up dissolved oxygen, and parting with it gradually to the tissues of the body.

It is instructive to notice that only such Chironomus larvæ as live at the bottom and burrow in the mud possess the red hæmoglobin. Those which live at or near the surface have colorless blood, and a more complete—though still closed—tracheal system. The larva of the carnivorous Tanypus, which is found in the same streams, but does not burrow, has a much more complete tracheal system, and only enough hæmoglobin to give a pale red tint to the body. The larva of the gnat, again, which has a large and open tracheal system, and in all stages of growth inhales gaseous air, has no hæmoglobin at all. A list of the many animals of all kinds which contain hæmoglobin shows that for some reason or another each of them requires to use oxygen economically. Either the skin is thick, and the respiratory surface limited, or they are inclosed in a shell or they burrow in earth or mud. We might expect to find that hæmoglobin would always be developed in the blood of animals whose respiration is rendered difficult in any of these ways, but any such expectation would prove to be unfounded, and there are many animals whose mode of life renders it necessary that oxygen

should be stored and economically used, which contain no hæmoglobin in their blood. Hence, while we have a tolerably satisfactory reason for the occurrence of hæmoglobin in a number of animals whose respiratory surface is limited, and whose surroundings make it a matter of difficulty to procure a sufficient supply of oxygen, we have to admit that many similar animals under the same conditions manage perfectly well without hæmoglobin. Such admission is not a logical refutation of the explanation. I might fairly put forward the baldness of mankind as at least the principal reason for wearing wigs, and this explanation would not be impaired by any number of cases of bald men who do not wear wigs. The fact is that the respiratory needs (even of closely allied animals) vary greatly, and further, there are more ways than one of acquiring and storing up oxygen in their bodies.

Either the storage capacity for oxygen of the Chironomus larva is considerable, or it must be used very carefully, for the animal can subsist long without a fresh supply. I took a flask of distilled water, boiled it for three-quarters of an hour, closed it tight with an India-rubber bung, and left it to cool. Then six larvæ were introduced, the small space above the water being at the same time filled up with carbonic acid. The bung was replaced and the larvæ was watched from day to day. Four of the larvæ survived for forty-eight hours, and one till the fifth day. Two of them changed to pupæ. Nevertheless, the water was from the first exhausted of oxygen, or nearly so.

The Chironomus larva is provided with implements suited to its mode of life. The head, which is extremely small and hard, carries a pair of stout jaws, besides a most complicated array of hooks, some fixed, some movable. The use of these minute appendages can not always be assigned, but some of them are apparently employed to guide the silky threads which issue from the salivary glands. The first segment behind the head carries a pair of stumpy legs, which are set with many hooks. These are mainly used in progression, and help the larva to hitch itself to and fro in its burrow. A similar, but longer pair of hooked feet, is found at the end of the body. This hinder pair serves to attach the animal to its burrow when it stretches forth in search of food.

Creeping aquatic larvæ, such as Ephydra, possess several pairs of legs in front of the last pair, but the burrowing species, such as caddis-worms, agree with Chironomus, not only in their mode of life, but also in the reduction of the abdominal legs to a single pair, which are conspicuously hooked.

The larval head in this, as in many other aquatic insects, is far smaller and simpler than that of the fly. The larval head is little more than an implement for biting and spinning, by no means such a seat of intelligence as it is in higher animals. In Chironomus it contains no brain; the eyes are mere specks of pigment, and the antennæ are insignificant. But the head of the fly incloses the brain, and bears elaborate organs of special sense—many-facetted eyes, and in the male

beautiful plumed antennæ. This difference in size and complexity probably explains the fact that the head of the fly is not developed within the larval head, but in the thorax. It is only at the time of pupation that it becomes everted, and its appendages assume the position which they are ultimately intended to occupy.

At length the Chironomus wiggles out of the larval skin, and is transformed into a pupa. It no longer requires to feed, and the mouth is completely closed. It is equally unable to burrow, and usually lies on the surface of the mud. Two tufts of silvery respiratory filaments project from the fore end of the body just behind the future head, and these wave to and fro in the water, as the animal alternately flexes and extends its body. At the tail end are two flaps, fringed with stout bristles, which form a kind of fan. The pupa virtually consists of the body of the fly, inclosed within a transparent skin. The organs of the fly are already complete externally, and even in microscopic detail they very closely resemble those of the perfect animal. These parts are however as yet very imperfectly displayed. The wings and legs are folded up along the sides of the body, and are incapable of independent movement. For two or three days there is no outward change, except that the pupa, which originally had the blood-red color of the larva, gradually assumes a darker tint. The tracheal system, which was quite rudimentary in the larva, but is now greatly enlarged, becomes filled with air, secreted from the water by the help of the respiratory tufts, and the pupa floats at the surface. At last the skin of the back splits, the fly extricates its limbs and other appendages, pauses for a moment upon the floating pupa case, as if to dry its wings, and then flies away.

This fly is a common object on our window-panes, and would be called a gnat by most people. It can be easily distinguished from a true gnat by its habit of raising the forelegs from the ground when at rest. It is entirely harmless, and the mouth parts can neither pierce nor suck. Like many other Diptera, the flies of Chironomus associate in swarms, which are believed in this case to consist entirely of males. The male fly has plumed antennæ, with dilated basal joints. In the female fly the antennæ are smaller and simpler, as well as more widely separated.

In brisk and lively streams another Dipterous larva may often be found in great numbers. This is the larva of Simulium, known in the winged state as the sand fly. The Simulium larva is much smaller than that of Chironomus, and its blood is not tinged with red. The head is provided with a pair of ciliary organs, fan-like in shape, consisting of many longish filaments, and borne upon a sort of stem. The fringed filaments are used to sweep the food into the mouth. The larva of Simulium subsists entirely upon microscopic plants and animals. Among these are great numbers of diatoms, and the stomach is usually found half full of the flinty valves of these microscopic plants. The Simulium larva seeks its food in rapid currents of water, and a brisk

flow of well-aërated water has apparently become a necessity to it. If the larvæ are taken out of a stream and placed in a vessel of clear water, they soon become sluggish, and in warm weather do not survive very long. It matters little however to the larvæ whether the water in which they live is pure or impure, and streams which are contaminated with sewage often contain them in great abundance. There are no externally visible organs of respiration, but the skin is supplied by an abundant network of fine tracheal branches, which, no doubt, take up oxygen from the well-aëated water in which the animal lives. From this network at the surface branches pass to supply all the internal organs. The Simulium larva is found upon aquatic weeds, and the pair of hindfeet, which in Chironomus were shaped so as to enable the larva to hold on to its burrow, here become altered, so as to furnish a new means of attachment. The two feet are completely united into one. The two clusters of hooks found in the Chironomus larva form now a circular coronet, and the center of the inclosed space becomes capable of being retracted by means of muscles which are inserted into it from within. The larva is thus enabled to adhere to the smooth surface of a leaf, holding on by its sucker, which is, no doubt, aided by the circle of sharp hooks. Efficient as this adhesive organ undoubtedly is, it must be liable to derangement by occasional accidents, as for instance if there should be a sudden rush of water of unusual violence, or if the larva should be obliged to quit its hold in order to avoid some dangerous enemy. In the case of such an accident it is not easy to see how it will ever recover its footing. Swept along in a rapid current, we might suppose that there would be but a slender probability of its ever finding itself favorably placed for the application of its sucker and hooks. But such emergencies have been carefully provided for. The salivary glands, or silk organs, which the Chironomus larva uses in weaving the wall of its burrow, furnish to the Simulium larva long mooring threads, by means of which it is anchored to the leaf upon which it lives. Even if the larva is dislodged, it is not swept far by the stream, and can haul itself in along the mooring thread in the same way that a spider or a Geometer larva climbs up the thread by which, when alarmed, it descended to the ground.

When the time for pupation comes special provision has to be made for the peculiar circumstances in which the whole of the aquatic life of the Simulium is passed. An inactive and exposed pupa, like that of Chironomus, may fare well enough on the soft muddy bottom of a slow stream, but such a pupa would be swept away in a moment by the currents in which Simulium is most at home. When the time of pupation draws near the insect constructs for itself a kind of nest, not unlike in shape the nest of some swallows. This nest is glued fast to the surface of a water-weed. The salivary glands, which furnished the mooring threads, supply the material of which the nest is composed. Sheltered within this smooth and tapering case, whose pointed tip is directed up-

stream, while the open mouth is turned down stream, the pupa rests securely during the time of its transformation.

When the pupa case is first formed it is completely closed and egg-shaped, but when the insect has cast the larval skin one end of the case is knocked off, and the pupa now thrusts the fore part of its body into the current of water. The respiratory filaments, which project immediately behind the future head, just as in Chironomus, draw a sufficient supply of air from the continually changed water around. The rings of the abdomen are furnished with a number of projecting hooks, which are able to grasp such objects as fine threads. The interior of the cocoon is felted by a number of silken threads, and by means of these the pupa gets an additional grip of its case. If it is forcibly dislodged a number of the silken threads are drawn out from the felted lining of the case. The fly emerges into the running water, and I do not know how it manages to do so without being entangled in the current of water and swept down stream. The pupa skin splits open just as it does in Chironomus, but remains attached to the cocoon.

The larva of the gnat is perhaps more familiar to naturalists of all kinds than any other aquatic dipterous insect. The interesting description, and above all the admirable engravings of Swammerdam, now more than two hundred years old, are familiar to every student of nature.

The larva, when at rest, floats at the surface of stagnant water. Its head, which is provided with vibratile organs suitable for sweeping minute particles into the mouth, is directed downwards, and when examined by a lens in a good light appears to be bordered below by a gleaming band. There are no thoracic limbs. The hind limbs, which were long and hooked in the burrowing Chironomus larva, and reduced to a hook-bearing sucker in Simulium, now disappear altogether. A new and peculiar organ is developed from the eighth segment of the abdomen. This is a cylindrical respiratory siphon, traversed by two large air tubes which are continued along the entire length of the body and supply every part with air. The larva ordinarily rests in such a position that the tip of the respiratory siphon is flush with the surface of the water, and thus suspended, it feeds incessantly, breathing uninterruptedly at the same time. When disturbed it leaves the surface by the sculling action of its broad tail. Once below the surface it sinks slowly to the bottom by gravity alone, which shows that the body is denser than the water. We have therefore to explain how it is enabled to float at the surface when at rest. The larva does not willingly remain below for any length of time. It rises by a jerking movement, striking rapid blows with its tail, and advancing tail foremost. When it reaches the top it hangs as before, head downwards, and resumes its feeding operations.

In order to explain how the larva hangs from the surface against gravity, I must trouble you with some account of the properties

of the surface film of water. You will readily believe that I have nothing new to communicate on this subject, and I venture to show you a few very simple experiments, merely because they are essential to the comprehension of what takes place in the gnat.*

In any vessel of pure water, the particles at the surface, though not differing in composition from those beneath, are nevertheless in a peculiar state. I will not travel so far from the region of natural history as to offer any theoretical explanation of this state, but will merely show you experimentally that there is a surface film which resists the passage of a solid body from beneath. [Mensbrugghe's float shown.] You see (1) that the float is sufficiently buoyant to rise well out of the water; (2) that, when forcibly submerged, it rises with ease through the water as far as the surface film; (3) that it is detained by the surface film, and can not penetrate it. The wire pulls at the surface film and distorts it, but is unable to free itself. In the same way the surface film resists the passage of a solid body which attempts to penetrate it from above. This will be readily seen if we throw a loop of aluminium wire upon the surface of water. [Experiment shown.] The loop of wire floats about like a stick of wood. Aluminium is, of course, much lighter than iron, but the floating of this little bar does not mean that it has a lower density than that of water. If the bar is once wetted, it sinks to the bottom and remains there. Even a needle may, with a little care, be made to float upon the surface of perfectly pure water. Still more readily can a piece of metallic gauze be made to float on water. [Experiment shown.] Air can pass through the meshes with perfect ease; water also can pass through the meshes with no visible obstruction. But the surface film, bounding the air and water, is entirely unable to traverse even meshes of appreciable size. These simple experimental results will enable us to appreciate certain facts of structure, which would otherwise be hard to understand, and which have been wrongly explained by naturalists of the greatest eminence, to whom the physical discoveries of this century were unknown.

We may now try to answer three questions about the larva of the gnat, viz:

(1) How is it able to break the surface film when it swims upwards?

(2) How is it able to remain at the surface without muscular effort, though denser than water?

(3) How is it able to leave the surface quickly and easily when alarmed?

The tip of the respiratory siphon is provided with three flaps, two large and similar to one another, the third smaller and differently shaped. These flaps can be opened or closed by attached muscles. When open they form a minute basin, which, though not completely closed, does not allow the surface film of water to enter. When closed

* A number of other experiments, illustrating the properties of the surface film of water, are described by Prof. Boys in his delightful book on "Soap Bubbles."

the air within the siphon is unable to escape. At the time when the larva rises to the surface the pointed tips of the flaps first meet the surface film and adhere to it. The attached muscles then separate the flaps, and in a moment the basin is expanded and filled with air. The surface film is now pulling at the edges of the basin, and the pull is more than sufficient to counterbalance the greater density of the body of the larva, which accordingly hangs from the surface without effort. When the larva is alarmed and wishes to descend the valves close, their tips are brought to a point, and the resisting pull of the surface film is reduced to an unimportant amount. [Living larvæ shown by the lantern.]

Swammerdam found it necessary in explaining the flotation of the larva of the gnat to suppose that the extremity of its siphon was supplied with an oily secretion which repelled the water. No oil gland can be discovered here or elsewhere in the body of the larva, and, indeed, no oil gland is necessary. The peculiar properties of the surface film explain all the phenomena. The surface film is unable to penetrate the fine spaces between the flaps for precisely the same reason that it is unable to pass through the meshes in a piece of gauze.

After three or four moults the larva is ready for pupation. By this time the organs of the future fly are almost completely formed, and the pupa assumes a strange shape, very unlike that of the larva.

At the head end is a great rounded mass, which incloses the wings and legs of the fly, besides the compound eyes, the mouth parts, and other organs of the head. At the tail end is a pair of flaps, which form an efficient swimming fan. The body of the pupa, like that of the larva, is abundantly supplied with air tubes, and a communication with the outer air is still maintained, though in an entirely different way. The air tubes no longer open toward the tail as in the larva, but toward the head. Just behind the head of the future fly is a pair of trumpets, so placed that in a position of rest the margins of the trumpets come flush with the surface of the water. Floating in this position the pupa remains still so long as it is undisturbed, but if attacked by any of the predatory animals which abound in fresh waters it is able to descend by the powerful swimming movements of its tail fin.

Not that the descent is without its difficulties. The pupa is not like the larva, denser than water, but buoyant. There are two respiratory tubes in the pupa, whereas there is only one in the larva, and to these two tubes the surface film clings with a tenacity of which only experiment can give an adequate idea. Will you allow me to give you a little more borrowed physics?

If we take a solid body, capable of being wetted by water, and place it in water, the surface film will adhere to the solid. If the solid is less dense than the water it will float with part of its surface out of the water. Under such circumstances the surface film will be drawn upwards around the solid, and will therefore pull the solid downwards.

But if the solid is denser than the water, the surface film around the solid will be pulled downwards, and will pull the solid upwards. Suppose that a solid of the same density as water floats with part of its surface in contact with air, and that weights are gradually added to it. The result will be that the surface of the water around the upper edge of the solid will become more and more depressed. The sides of the depression will take a more vertical position, until at last the upward pull of the film becomes unable to withstand further increase of weight. If this point is passed, the solid will sink. Before this point is attained, we shall have the solid, though denser than water, kept at the surface by the pull of the surface film.

This state of things may be illustrated by a model. [Float with glass tube attached to its upper surface.] You will readily see that the float has to be weighted appreciably in order to break the connection of the tube with the surface film. Now the pupa of the gnat has a pair of tubes which are in like manner attached to the surface of the water. When it requires to descend, the pull of the surface film would undoubtedly be considerable. Adding weight to the body is, of course, impossible, and a great exertion of muscular force would be wasteful of energy, even if it could be put forth. The gnat deals with its difficulty in a neater way than this, and saves its muscular power for other occasions. Let me show you a method of freeing the float from the surface, which was suggested by observation of what was seen in the pupa of the gnat. A thread wetted with water is drawn over the mouth of each tube. It cuts the connection with the surface, and the float, loaded so as to be denser than water, goes down at once. Meinert has described a pencil of hairs which appear to perform the same office for the pupa of the gnat. The hairs draw a film of water over the open mouth of each respiratory tube, and muscular contraction, used moderately and economically, does the rest. When the pupa again comes to the surface the tubes are overspread by a glistening film of water. This is partially withdrawn by a movement of the hairs, so that a chink appears by which air can be slowly renewed. When the insect is completely tranquil, the hairs appear to withdraw more completely, and the tube suddenly becomes free of all film. The act of opening or closing the film is so rapid—like the wink of an eye—that I can not pretend to have observed more than the closed tube, the slightly open tube, and then the sudden change to a completely open condition. [Living pupæ shown by the lantern.]

Another Dipterous larva described and admirably figured by Swammerdam is the larva of Stratiomys, a larva which, as the structure of the fly shows, belongs to an altogether different group from Chironomus, Simulium, or the gnat. Though only remotely connected with the gnat in the systems of zoölogists, the Stratiomys larva has learned the same lesson, and is equally well fitted to take advantage of the peculiar properties of the surface film. The tail end of the Stratiomys larva is provided with a beautiful coronet of branched filaments. When the

coronet is extended it forms a basin open to the air and impervious to water, by reason of the fineness of the meshes between the component filaments. Were the larva provided with a basin of the same proportions formed out of continuous membrane, it might float and breathe perfectly well, but the old difficulty would come back, viz, that of freeing itself neatly and quickly when some sudden emergency required the animal to leave the surface. As it is, the plumed filaments collapse and their points approach; the side branches are folded in, and the basin is in a moment reduced to a pear-shaped body, filled with a globule of air, and reaching the surface of the water only by its pointed extremity. Down goes the Stratiomys larva at the first hint of danger, swimming through the water with swaying and looping movements, somewhat like those of Chironomus. When the danger is past, it ceases to struggle and floats again to the surface. The pointed tip of its tail fringe pierces the surface film, the filaments separate once more, and the floating basin is restored.

The larva of Stratiomys is extremely elongate. The length of its body has evidently some relation to the mode of life of the larva, but none at all to that of the fly which is formed within it. The pupa is so much smaller than the larva as to occupy only the fore part of the space within the larval skin.* The interval becomes filled with air, and during the pupal stage the animal floats at the surface within the empty larval skin.

Stratiomys, both in its larval and pupal states, floats at the surface of the water. The larva can descend into the water when attacked, but the pupa is too buoyant, and too much encumbered by its outer case, to execute any such maneuver. Provision has accordingly to be made for the protection of the helpless pupa against its many enemies. It is probable that hungry insects and birds mistake the shapeless larval skin, floating passively at the surface, for a dead object. The considerable space between the outer envelope, or larval skin, and the body of the pupa may keep off others, for the first bite of a Dytiscus or dragon-fly larva would be disappointing. Still further security is gained by the texture of the larval skin itself. The cuticle consists of two layers. The inner is comparatively soft and laminated, while the outer layer is impregnated with calcareous salts, and extremely hard. The needful flexibility is obtained by the sub division of the hard outer layer. Seen from the surface, it is broken up into a multitude of hexagonal fields, each of which forms the base of a conical projection, reaching far into the softer layer beneath. The conical shape of these calcareous nails allows a certain amount of bending of the cuticle, while the whole exposed surface is protected by an armor, in which even the pointed mandibles of a Dytiscus larva can find no effective chink.

* So singular is the disproportion between the larva and the pupa that some naturalists have actually described the latter as a parasite (Westwood's "Mod. Classification of Insects," vol. II, p. 532).

The larva and pupa of the Dipterous fly, *Ptychoptera paludosa*, exhibit some interesting adaptations of the tracheal system to unusual conditions. The larva is found in muddy ditches, where it buries itself in the black ooze to a depth of an inch or two. Here, of course, it can procure no oxygen, either gaseous or dissolved. When it requires a fresh supply, it must reach the surface with part of its body, and to enable it to do so with the least possible exertion, the tail end of the body is made telescopic, like that of another and still more familiar Dipterous larva, Eristalis. The last segments are drawn very fine, and are capable of a very great amount of retraction or expansion. No visible opening for the admission of air has been discovered, nor do the hairs form a floating basin, as in the Stratiomys larva. The larva may be often seen lying just beneath the surface, which is broken by the tip of the tail. Whether air can be admitted here by some very minute orifice, or whether it is renewed by the exchange of gases through a thin membrane, I can not as yet venture to say. In shallow water the larva may be occasionally found lying on or in the mud, and stretching out its long tail to the surface. In deeper water it often floats at the surface.

Two tracheal trunks run along the whole length of the body, including the slender tail, where they are extremely convoluted and unbranched. Toward the middle of the body the tracheæ become greatly enlarged in the center of each segment, the intervening portions, from which many branches are given off, being comparatively narrow. Each tube therefore resembles a row of bladders connected by small necks. A cross section shows that the tubes are not cylindrical, but flattened, and that, while the lower surface is stiffened by the usual parallel thickenings, the upper surface is thrown into two deep longitudinal furrows, so that it is really inflated, becoming circular in section, and readily collapses again when the air is expelled. It seems likely that the buoyancy of the larva can thus be regulated, and a larger or smaller quantity of air taken in as desired.

The pupa has a pair of respiratory tubes, which are carried, not on the tail, but on the thorax, close behind the head. One of these tubes is very long, the other very short. The long tube is twice as long as the body and tapers very gradually to its free tip. Here we find a curious radiate structure, rather like the teeth of a moss-capsule, which seems adapted for opening and closing. There is however no orifice which the most careful scrutiny has succeeded in discovering. A delicate membrane extends between the teeth, and prevents any passage inward or outward of air in mass. The tube incloses a large trachea, the continuation of one of the main tracheal trunks. This is stiffened by a spiral coil, but at intervals we find the coil deficient, while the wall of the tube swells out into a thin bladder. However the tube is turned, a number of these bladders come to the surface. As the pupa lies on the surface of the mud, the filament floats on the top of the

water, and the air is renewed without effort through the thin-walled bladders.

Why should the position of the respiratory organs be changed from the tail end in the larva to the head end in the pupa? Chironomus, the gnat, Corethra, and many other aquatic insects exhibit the same phenomena. Evidently there must be some reason why it is more convenient for the larva to take in air by the tail, and for the pupa to take in air by the head. Let us consider the case of the larva first. Where it floats from the surface, or pushes some part of its body to the surface, it is plain that the tail must come to the top and bear the respiratory outlet, for the head bears the mouth and mouth organs, and must sweep to and fro in all directions, or even bury itself in the mud in quest of food. To divide the work of breathing and feeding between the opposite ends of the body is of obvious advantage, for the breathing can be done best at the top of the water, and the feeding at the bottom, or at least beneath the surface. Such considerations seem to have fixed the respiratory organs at the tail of the larva. Why then need this arrangement be reversed when the insect enters the pupal stage? There is now no feeding to be done, and it surely does not signify how the head is carried. Why should not the pupa continue to breathe like the larva, by its tail, instead of developing a new apparatus at the opposite end of its body, as if for change's sake? Well, it does not appear that, so far as the pupa itself is concerned, any good reason can be given why the larval arrangement should not continue. But a time comes when the fly has to escape from the pupa case. The skin splits along the back of the thorax, and here the fly emerges, extricating its legs, wings, head, and abdomen from their close-fitting envelopes. The mouth parts must be drawn backward out of their larval sheaths, the legs upward, and the abdomen forward, so that there is only one possible place of escape, viz, by the back of the thorax, where all these lines of movement converge. If then the fly must escape by the back of the thorax, the back of the thorax must float uppermost during at least the latter part of the pupal stage. Otherwise the fly would emerge into the water instead of into the air. Granting that the back of the thorax must float uppermost in the pupal condition, it is clear that here the respiratory tubes must be set.

I need hardly speak of the many insects which run and skate on the surface of the water in consequence of the peculiar properties of the surface film. They are able to do so, first, by reason of their small size; secondly, because of the great spread of their legs; and thirdly, on account of the fine hairs with which their legs are provided. The adhesion of the surface film is measured by the length of the line of contact, and accordingly the multiplication of points of contact may indefinitely increase the support afforded by the surface of the water.

In the case of very small insects it becomes possible not only to run on the surface of the water but even to leap upon it, as upon a table This is particularly well seen in one of the smallest and simplest of all insects—the little black Podura, which abounds in sheets of still water. The minute and hairy body of the Podura is incapable of being wetted, and the insect frisks about on the silvery surface of a pond, just as a house fly might do on the surface of quicksilver. This is all very well so long as the Podura is anxious only to amuse itself, or move from place to place, but it has to seek its food in the water, and, indeed, the attractiveness of a sheet of water to the Podura lies mainly in the decaying vegetation far below the surface. But, if the insect is thus incapable of sinking below the surface, how does it ever get access to its submerged food? I have endeavored to arrive at the explanation of this difficulty by observation of Poduras in captivity. If you place a number of Poduras in a beaker half full of water, they are wholly unable to sink. They run about and leap upon the surface, as if trying to escape from their prison, but sink they can not. I have chased them about with a small rod until they became excited and much alarmed, but they were wholly unable to descend. Even when large quantities of alcohol were added to the water the dead bodies of the Podura are seen floating at the top, almost as dry as before. It is only when they are placed upon the surface of strong alcohol that the dead bodies become wetted, and after a considerable time are seen to sink. How, then, does the Podura ever descend to the depths where its food is found?

I found it an easy matter to make a ladder, by which the Poduras could leave the upper air. A few plants of duck-weed introduced into the beaker enabled them at pleasure to pull themselves forcibly through the surface film, and climb down the long root hanging into the water like a rope. Once below the surface, the Podura, though buoyant, is enabled, by muscular exertion, to swim downwards to any depth.

Other aquatic insects, not quite so minute as the Podura, experience something of the same difficulty. A Gyrinus, or a small Hydrophilus, finds it no easy matter to quit the surface of the water, and is glad of a stem or root to descend by.

To leave our aquatic insects for a moment, we may notice the habit of creeping on the under side of the surface film, which is so often practiced by leeches, snails, cyclas, etc. I find this is often described as creeping on the *air*, and some naturalists of the greatest eminence speak of fresh-water snails as creeping "on the stratum of air in contact with the surface of the water."* The body of the animal is, nevertheless, wholly immersed during this exercise, as may be shown by a simple experiment. If Locopodium powder is sprinkled over the water the light particles are not displaced by the animal as it travels beneath.

* Semper's "Animal Life," Eng. trans., p. 205, and note 97.

The possibility of creeping in this manner depends, not upon any "repulsion between the water and the dry surface of the body," to quote an explanation which is often given, but upon the tenacity of the surface film, which serves as a kind of ceiling to the water chamber below. The body of the leech is distinctly of higher specific gravity than the water, and falls quickly to the bottom, if the animal loses its hold of the surface film. The pond snails however actually float at the surface, and if disturbed, or made to retract their foot, they merely turn over in the water.

What is the result of all the expedients which have enabled air-breathing insects to overcome the difficulties of living in water? They have been successful, we might almost say too successful, in gaining access to a new and ample store of food. Aquatic plants, minute animals, and dead organic matter of all kinds abound in our fresh waters. Accordingly the species of aquatic insects have multiplied exceedingly, and the number of individuals in a species is sometimes surprisingly high. The supply of food thus opened out is not only ample, but in many cases very easy to appropriate. Accordingly the head of the larva degenerates, becomes small and of simple structure, and may be in extreme cases reduced to a mere shell, not inclosing the brain, and devoid of eyes, antennæ, and jaws. The organs of locomotion also commonly afford some indications of degeneration. Where the insect has to find a mate, and discover suitable sites for egg-laying, the fly at least must possess some degree of intelligence, keen sense organs, and means of rapid locomotion. But some few aquatic insects, as well as some non-aquatic species which have found out an unlimited store of food, manage to produce offspring from unfertilized eggs, and to have these eggs laid by wingless pupæ or hatched within the bodies of wingless larvæ. The development of the winged fly, the whole business of mating, and even the development of the embryo within the egg, have thus, in particular insects, been abbreviated to the point of suppression. This is what I mean by saying that the pursuit of a new supply of food has in the case of certain aquatic insects proved even too successful. Abundant food, needing no exertion to discover or appropriate it, has led in a few instances to the almost complete atrophy of those higher organs and functions which alone make life interesting.

# THE GEOGRAPHIC DISTRIBUTION OF LIFE IN NORTH AMERICA.

## WITH SPECIAL REFERENCE TO THE MAMMALIA.*

By C. linton Hart Merriam, M. D.

Nine years ago the Biological Society listened to an address from its distinguished retiring president, Prof. Gill, on "The Principles of Zoö-geography," or the science of the geographical distribution of animals.† Prof. Gill assembled the oceans of the globe as well as the land areas into primary divisions or "zoölogical realms," of which he recognized nine for the land and five for the sea. It is not my purpose to discuss the zoölogical regions of the whole world, but to lay before you some of the facts concerned in the distribution of terrestrial animals and plants in North America with special reference to the number and boundaries of the subregions and minor life areas, and to touch upon the causes that have operated in their production.

No phenomenon in the whole realm of nature forced itself earlier upon the notice of man than certain facts of geographic distribution. The daily search for food, the first and principal occupation of savage man, directed his attention to the unequal distribution of animals and plants. He not only noticed that certain kinds were found in rivers, ponds, or the sea, and others on land, and that some terrestrial kinds were never seen except in forests, while others were as exclusively restricted to open prairies, but he observed further, when his excursions were extended to more distant localities or from the valleys and plains to the summits of neighboring mountains, that unfamiliar fruits and insects and birds and mammals were met with, while those he formerly knew disappeared.

*Annual Presidential Address, delivered at the twelfth anniversary meeting of the Biological Society of Washington, February 6, 1892. (From the *Proc. Biolog. Soc.*, Washington, vol. VII, pp. 1–64.)

† *Proc. Biolog. Soc.*, Washington, 1884, vol. II, pp. 1–39.

Thus primeval man, and in truth the ancestors of primeval man, learned by observation the great fact of geographic distribution, the fact that particular kinds of animals and plants are not uniformly diffused over the earth, but are restricted to more or less circumscribed areas.

It will be observed that two classes of cases are here referred to, namely, (1) cases in which in the same general region certain species are restricted to swamps or lowlands, while others are confined to dense forests or rocky hillsides—differences of *station*, and (2) cases in which, regardless of *local* peculiarities, a general change takes place in the fauna and flora in passing from one region to another, or from low valleys or plains to high mountains—*geographic* differences. The latter class only is here considered.

Every intelligent school-boy knows that elephants, lions, giraffes, and chimpanzees inhabit Africa; that orangs and flying lemurs live in Borneo; kangaroos in Australia; the apteryx in New Zealand; the Royal Bengal tiger in India; llamas, chinchillas, and sloths in South America; the yak in the high table lands of Thibet, and so on. In accordance with these facts naturalists long ago began to divide the surface of the globe into zoölogical and botanical regions irrespective of the long-recognized geographic and political divisions.* It was found that different degrees of relationship exist between the indigenous animals and plants of different countries, and that as a rule the more remote and isolated the region and the earlier in geologic time its separation took place, the more distinct were its inhabitants from those of other regions. Each of the larger islands lying near the equator and the continental masses of the southern hemisphere were found to possess not only peculiar species and genera, but even families and orders not found elsewhere; and it was discovered that insular areas of considerable magnitude that have had no land connection with other areas since very early times possess faunas and floras remarkable for the antiquity of their dominant types. In Australia, the most disconnected of all the continents, the entire mammalian fauna, though wonderfully diversified in appearance and habits, belongs to the primitive orders of monotremes and marsupials, whose best known representatives are the duck-billed platypus and the kangaroo. In the latter group Australia and neighboring islands contain no less than six families not found in any other part of the world.

Madagascar is the exclusive home of the remarkable aye-aye (*Chiromys*) and *Cryptoprocta*, the latter believed to be intermediate between the cats and civets.

*Among the many distinguished naturalists who have contributed to the literature of the subject may be mentioned Humboldt, Bonpland, Buffon, De Candolle, Schouw, Engler, Agassiz, Baird, Asa Gray, Grisebach, Huxley, Gill, Allen, Wallace, and Packard.

Tropical America is alone in the possession of true ant-eaters (*Myrmecophagidæ*), sloths (*Bradypodidæ*), marmosets (*Hapalidæ*), armadillos (*Dasypodidæ*), and agouties (*Dasyproctidæ*).

Africa is the home of many groups not known elsewhere. Among them are the giraffe, hippopotamus, *Orycteropus*, elephant shrews (*Macroscelididæ*), *Potomogale*, and *Chrysochloridæ*.

Besides this class of cases, in which particular groups are restricted to particular countries, there is another class, in which the living representatives of single groups exist in isolated colonies in widely separated parts of the world. Illustrations of this kind are furnished by the tapirs, which inhabit tropical America and the Malay Peninsula, but do not exist in intermediate lands; by the family *Camelidæ*, represented in South America by the llamas and in parts of Eurasia by the true camels; and by a group of insectivorous mammals in which all the genera but one are restricted to Madagascar, the one exception (*Solenodon*) living in Cuba and Haiti. Examples of this sort are known as cases of *discontinuous* distribution, and indicate that the ancestors of the animals in question formerly inhabited a vast extent of country; that some sort of land connection, however indirect, existed between the colonies now so widely separated, and that the surviving descendants of these groups are probably approaching extinction.

The examples thus far cited relate to the disconnected land areas in the neighborhood of the equator or in the southern hemisphere, and their explanation is to be sought in the history of the past. In the northern hemisphere animals and plants in general have a much more extended distribution than in the southern, the majority of the larger groups being common to North America, Europe, and Asia, and the limits of their distribution are encountered in traveling in a north and south direction and are evidently the result of causes now in operation. It is to this class of cases as presented on the North American continent that your attention is invited this evening.

In passing from the tropics to the Arctic pole on the eastern side of America a number of distinct zones are crossed, the most conspicuous features of which are well known. In the plant world the palms, mangroves, mahogany, mastic, Jamaica dogwood, and cassias of the tropical coast districts are succeeded by the magnolias, papaws, sweet gums, blackberries, and persimmons of the Southern States. These give place gradually to the oaks, chestnuts, and hickories of the Middle States, and the latter to the groves of aspen, maple, and beech which reach the southern edge of the great coniferous forest of the north,—a forest of spruces and firs that stretches completely across the continent from Labrabor to Alaska. Beyond this forest is a treeless expanse whose distant shores are bathed in the icy waters of the Arctic Ocean.

Concurrently with these changes in vegetation from the south northward occur equally marked differences in the mammals, birds, reptiles,

and insects. Among mammals the tapirs, monkeys, armadillos, nasuas, peccaries, and opossums of Central America and Mexico are replaced to the northward by wood-rats, marmots, chipmunks, foxes, rabbits, short-tailed field-mice of several genera, shrews, wild-cats, lynxes, short-tailed porcupines, elk, moose, reindeer, sables, fishers, wolverines, lemmings, musk oxen, and polar bears.

The trogons, saw bills, parrots, cotingas, and other birds of tropical America give place in turn to the cardinals, blue grosbeaks, mocking birds, tufted tits, and gnat-catchers of the Southern States; the chewink, indigo bird, tanager, bluebird, and robin of the Middle and Northern States; the Canada jays, crossbills, white-throated sparrows, and hawk owls of the northern coniferous forests, and the ptarmigans, snowy owls, and snowflakes of the Arctic circles.

## HISTORICAL SYNOPSIS OF FAUNAL AND FLORAL DIVISONS PROPOSED FOR NORTH AMERICA.

The recognition of the above-mentioned facts early led to attempts to divide the surface of the land into faunal and floral regions or zones, and no less than fifty-six authors have proposed such divisions for North America. Of these, thirty-one were zoölogists and twenty-five botanists. Of the zoölogists ten aimed to show the distribution of animals in general, eight of birds, four of terrestrial mollusks, three of mammals, one of reptiles and batrachians, and four of insects. Of the botanists, twenty-two aimed to show the distribution of plants in general and three of forest trees.

Of the writers who attempted to indicate the life areas of the New World prior to 1850, 68 per cent were botanists, while during the next twenty years (1850–1870), 65 per cent were zoölogists. This striking oscillation of the biological pendulum, first toward botany and then toward zoölogy, may be attributed in part at least to the influence of two great minds—Humboldt and Agassiz. Humboldt laid the corner-stone of the philosophic study of plant geography in 1805. Stimulated by his example and writings, botanists led the way and were almost the only occupants of the field until the middle of the present century, when the influence of the elder Agassiz gained the ascendancy and the botanists were replaced by zoölogists, who have been in the lead ever since.

The accompanying table shows the various authors referred to, the dates of the earliest publication of their divisions, the branch of biology on which their conclusions were based, and states whether or not their articles were accompanied by maps.

| Author. | Date. | Study based on— | Accompanied by maps. | Author. | Date. | Study based on— | Accompanied by maps. |
|---|---|---|---|---|---|---|---|
| Latreille | 1817 | Insects | No | Verrill | 1863 | Birds | No. |
| De Candolle (Aug.) | 1820 | Plants | do | Baird | 1866 | do | Do. |
| Schouw | 1822 | do | Yes | Murray | 1866 | Mammals | Yes. |
| Martius | 1824-'26 | do | do | Grisebach | 1866 | Plants | Do. |
| Minding | 1829 | Mammals | No | Huxley | 1868 | Animals | Do. |
| Pickering | 1830 | Plants | Yes | Brown | 1870 | Forests | Do. |
| Lesson | 1831 | Birds | No | Allen | 1871 | Animals | No. |
| De Candolle (Alph.) | 1835 | Plants | do | Blyth | 1871 | do | Do. |
| Meyen | 1836 | do | do | Cope | 1873 | Repts. and batrchs. | Yes. |
| Pompper | 1841 | Animals | do | Porter | 1874 | Plants | Do. |
| Berghaus | 1838 | Plants | Yes | Scudder | 1874 | Insects | Do. |
| Martens and Galeotti | 1842 | do | No | Wallace | 1876 | Animals | Do. |
| Hinds | 1843 | do | do | Dyer | 1878 | Plants | No. |
| Frankenheim | 1843 | do | do | Engler | 1882 | do | Yes. |
| Wagner | 1844 | Mammals | Yes | Packard | 1883 | Animals | Do. |
| Richard and Galeotti | 1844 | Plants | No | Jordan | 1883 | Mollusks | Do. |
| Binney (A.) | 1851 | Mollusks | do | Sargent | 1884 | Forests | Do. |
| Richardson | 1851 | Plants | do | Drude | 1884 | Plants | Do. |
| Schmarda | 1853 | Animals | Yes | Hartlaub | 1886 | Birds | Do. |
| Agassiz | 1854 | do | do | Reichenow | 1887 | do | Do. |
| Gray | 1856 | Plants | No | Heilprin | 1887 | Animals | Do. |
| Woodward | 1856 | Mollusks | Yes | Hemsley | 1887 | Plants | Do. |
| Sclater | 1858 | Birds | No | Brendel | 1887 | do | No. |
| Le Conte | 1859 | Insects | Yes | Nelson | 1887 | Birds | Do. |
| Cooper | 1859 | Forests | do | Schwarz | 1888 | Insects | Do. |
| Hooker | 1861 | Plants | do | Bessey | 1888 | Plants | Do. |
| Binney (W. G.) | 1863 | Mollusks | do | Ridgway | 1889 | Birds | Do. |
| | | | | Merriam | 1890 | Animals and plants. | Yes. |
| | | | | Keeler | 1891 | Birds | Do. |

The principal bio-geographic divisions that have been recognized by a large number of writers, and as a rule have been proposed independently and under different names, resulting from the study of different groups, are described in the following synopses, each of which may be regarded as a chronologic synonymy of the region to which it refers.

### ARCTIC DIVISION (ABOVE LIMIT OF TREES).

An Arctic circum-polar division north of the limit of tree growth was recognized as a distinct region by European writers long before the earliest attempts were made to map the faunal and floral areas of North America.* Hence the following table is necessarily incomplete, since

* This region, however, is not universally recognized. Wallace and a few others refuse to accept it. Agassiz, Allen, and most botanical writers, on the other hand, regard it as one of the best defined of the primary divisions. An important recent treatise on the subject, from the standpoint of the distribution of mammals, is the following: "*Die arktische Subregion—Ein Beitrag zur geographischen Verbreitung der Thiere,*" by Dr. August Brauer (*Zoologische Jahrbucher, Abth. fur. Syst.*, III, Jan., 1888, 189–308, taf. viii).

it shows only the extent to which this zone has been recognized by those who have actually defined faunal and floral areas in North America:

| Date. | Author. | Name given to region. | Study based on— | Rank. |
|---|---|---|---|---|
| 1820 | De Candolle | Hyperboreal region | Plants | 1 |
| 1822 | Schouw | Realm of Mosses and Saxifrages | ...do | 1 |
| 1830 | Pickering | Arctic region | ...do | 1 |
| 1831 | Lesson | ...do | Birds | 1 |
| 1835 | De Candolle | ...do | Plants | 1 |
| 1836 | Meyen | Polar zone | ...do | 1 |
| 1838 | Berghaus | Realm of Mosses and Saxifrages | ...do | 1 |
| 1843 | Hinds | Greenland region | ...do | 1 |
| 1844 | Wagner | Polar province | Mammals | 2 |
| 1853 | Schmarda | Barren grounds | Animals | 2 |
| 1854 | Agassiz | Arctic realm | ...do | 1 |
| 1856 | Woodward | Region of Saxifrages and Mosses | Mollusks | 1 |
| 1858 | Cooper | Arctic province | Plants | 1 |
| 1866 | Grisebach | Arctic-Alpine region | ...do | 1 |
| 1870 | Brown | Treeless or Eskimo province | Forests | 1 |
| 1871 | Allen | Arctic realm | Animals | 1 |
| 1875 | Cope | ...do | ...do | 1 |
| 1878 | Dyer | Arctic-Alpine flora | Plants | 2 |
| 1882 | Engler | Arctic region | ...do | 2 |
| 1883 | Packard | Arctic realm | Animals | 1 |
| 1883 | Jordan | Arctic province | Mollusks | 2 |
| 1884 | Drude | Arctic district | Plants | 2 |
| 1887 | Brendel | Arctic-Alpine division | ...do | 1 |
| 1887 | Reichenow | Arctic zone | Birds | 1 |
| 1887 | Nelson | Arctic district (Alaskan) | ...do | 1 |
| 1888 | Brauer | Arctic sub-region | Mammals | 2 |
| 1890 | Merriam | Arctic region | Animals and plants. | 2 |

BOREAL DIVISION.

This heading is intended to cover the zone of coniferous forests extending across the continent south of the Arctic realm. While its northern boundary is fixed at the limit of trees, its southern border has been variously placed by different writers. Schouw did not recognize it at all, but carried his great forest region down to latitude 36°, where the true southern district begins. Berghaus, who in other respects followed Schouw, divided this great region into two parts, the northernmost of which he named the "Realm of conifers," placing its southern limit in the east at about latitude 47°. Hinds, Agassiz, Woodward, Verrill, and Drude speak of it as the "Canadian" region. Its southern limit is here extended to include the "Canadian fauna" of recent zoölogical writers.

The extent to which this zone has been recognized will appear from the following table:

| Date. | Author. | Name given to region. | Study based on— | Rank. |
|---|---|---|---|---|
| 1830 | Pickering | Canadian flora | Plants | 2 |
| 1838 | Berghaus | Realm of conifers | ...do | 1 |
| 1843 | Hinds | Canadian region | ...do | 1 |
| 1853 | Schmarda | Region of coniferous forests | Animals | 2 |
| 1854 | Agassiz | Canadian fauna | ...do | 2 |
| 1856 | Woodward | Canadian province | Mollusks | 1 |
| 1856 | Gray | Middle and northern wooded district | Plants | (?) |
| 1859 | Le Conte | Northern province | Insects | 2 |
| 1859 | Cooper | Lacustrian province | Forests | 1 |
| 1863 | Verrill | Canadian fauna | Birds | 1 |
| 1863 | Binney | Northern region | Mollusks | 3 |
| 1870 | Brown | Lacustrian province | Forests | 1 |
| 1871 | Allen | Hudsonian and Canadian faunas | Animals | 3 |
| 1882 | Engler | Region of conifers | Plants | 2 |
| 1883 | Packard | Boreal province | Animals | 1 |
| 1884 | Sargent | Northern forest | Forests | 2 |
| 1884 | Drude | Canadian district | Plants | 2 |
| 1890 | Merriam | Boreal region | Animals and plants. | 2 |

ATLANTIC, CENTRAL, AND PACIFIC DIVISIONS OF TEMPERATE NORTH AMERICA.

It has been the custom of recent writers to divide the broad middle zone of North America (most of which lies within the United States) into three main divisions—Atlantic or Eastern, stretching from the Atlantic Ocean to the eastern border of the plains; Central, from the plains to the Sierra Nevada; and Pacific, from the Sierra to the Pacific Ocean.* These regions were proposed as early as 1854 by the elder Agassiz, who however divided the Eastern or Atlantic district into two regions of equal rank—Alleghanian and Louisianian, or faunas of the Middle and the Southern States. In this respect he has been followed by Cope. Other authors, including Le Conte, Baird, and Allen, regard the southern district as only a subdivision of the Eastern region. Agassiz named the Central region the "Table-land or Rocky Mountain fauna" and the Pacific the "Californian fauna."

This arrangement of the United States into three provinces has been followed in the main by Le Conte (1859), W. G. Binney (1863), Baird (1866), Cope (1873), Grisebach (1875), Wallace (1876), Allen (1878), Packard (1883), Jordan (1883), Hartlaub & Newton (1886), and Heilprin (1887).

The three divisions will be considered separately.

*Atlantic or eastern forest region.*—Many writers have recognized an eastern forest region stretching from the plains to the Atlantic and in a general way from the boreal or coniferous forests of the north to the

*These divisions must not be confounded with those of Amos Binney (published in 1851) bearing the same names, for Binney's Atlantic region lay between the Atlantic and the Alleghanies, his Central region between the Alleghanies and the Rocky Mountains, and the Pacific region between the Rocky Mountains and the Pacific. Woodward's divisions (1856) are essentially those of Amos Binney.

alluvial lands of the South Atlantic and Gulf States; but its northern and southern limits have been by no means agreed upon. Schouw defined these boundaries as the limit of trees on the north and latitude 36° on the south, and named the region Michaux's realm or realm of asters and solidagos. Berghaus retained Schouw's southern boundary, but took off a broad belt on the north, which he named the realm of coniferous forests. The resulting northern limit, as shown on his map (1838), agrees closely with that adopted by such recent writers as Wallace (1876), Allen (1878), Packard (1883), and Heilprin (1887), all of whom, on the other hand, carry its southern boundary south to the Gulf of Mexico, thus making it coextensive with the Atlantic or Eastern province already referred to.

Several early writers, among whom Schouw and Berghaus were prominent, recognized this region in the east, but knew nothing of the great interior plans, and consequently spoke of it as extending all the way to the Rocky Mountains.

The extent to which this Eastern forest region has been recognized, together with the approximate north and south boundaries assigned it, will appear from the following table:

NOTE.—In the columns showing limit on the north and south the following abbreviations are used: L. T.=northern limit of trees; C. F.=northern coniferous forests; A.=Austro-riparian or Louisiana region; G.=Gulf of Mexico.

| Date. | Author. | Name given to region. | Limit on the— | | Based on— | Rank. |
|---|---|---|---|---|---|---|
| | | | North. | South. | | |
| 1822 | Schouw | Asters and solidagos | L. T. | A. | Plants | 1 |
| 1830 | Pickering | Flora of United States | C. F. | G. | ....do | 2 |
| 1838 | Berghaus | Asters and solidagos | C. F. | A. | ....do | 1 |
| 1843 | Hinds | Iroquoian | C. F. | G. | ....do | 1 |
| 1848 | Frankenheim | New England | C. F. | A. | ....do | 2 |
| 1854 | Agassiz | Alleghanian | C. F. | A. | Animals | 2 |
| 1856 | Gray | Northern States | (?) | A. | Plants | 1 |
| 1859 | Le Conte | Eastern | (?) | G. | Insects | 1 |
| 1859 | Cooper | Appalachian | C. F. | G. | Forests | 1 |
| 1863 | Verrill | Alleghanian | C. F. | A. | Birds | 1 |
| 1863 | Binney (W. G.) | Interior | C. F. | A. | Mollusks | 2 |
| 1866 | Baird | Eastern | C. F. | G. | Birds | 1 |
| 1866 | Grisebach | Forest | L. T. | G. | Plants | 1 |
| 1870 | Brown | Appalachian | C. F. | G. | Forests | 1 |
| 1871 | Allen | Eastern | C. F. | G. | Animals | 2 |
| 1873 | Cope | ....do | (?) | A. | ....do | 2 |
| 1874 | Porter | Forest | C. F. | G. | Plants | 1 |
| 1876 | Wallace | Alleghanian | C. F. | G. | Animals | 2 |
| 1882 | Engler | Appalachian province | C. F. | G. | Plants | 3 |
| 1883 | Packard | Eastern | C. F. | G. | Animals | 1 |
| 1883 | Jordan | Atlantic region | C. F. | G. | Mollusks | 3 |
| 1884 | Sargent | Deciduous forests | C. F. | A. | Forests | 2 |
| 1884 | Drude | Virginian | C. F. | G. | Plants | 2 |
| 1886 | Hartlaub | Alleghanian | C. F. | G. | Birds | 2 |
| 1887 | Heilprin | ....do | C. F. | G. | Animals | 2 |
| 1887 | Brendel | Mixed forest | C. F. | G. | Plants | 2 |
| 1889 | Ridgway | Eastern province | (?) | G. | Birds | 1 |

*Central or middle division.*—This division extends from the eastern border of the great plains to the Sierra Nevada and Cascade Mountains. It was proposed by Agassiz in 1854, under the name "Table-land fauna or fauna of the Rocky Mountains."

The extent to which it has been recognized will appear from the following table:

| Date. | Author. | Name given to region. | Based on— | Rank. |
|---|---|---|---|---|
| 1854 | Agassiz | Table-land fauna | Animals | 3 |
| 1859 | Le Conte | Central district | Insects | 1 |
| 1863 | Binney (W. G.) | Central province | Mollusks | 1 |
| 1866 | Baird | Middle province | Birds | 1 |
| 1866 | Grisebach | Prairie region | Plants | 1 |
| 1873 | Cope | Central region | Reptiles and batrachians. | 2 |
| 1876 | Wallace | Rocky Mountain sub-region | Animals | 2 |
| 1878 | Allen | Middle province | do | 2 |
| 1881 | Gray | Central province | Plants | 1 |
| 1883 | Packard | do | Animals | 1 |
| 1883 | Jordan | Central region | Mollusks | 3 |
| 1884 | Drude | Montana district | Plants | 2 |
| 1886 | Hartlaub | Rocky Mountain region | Birds | 2 |
| 1887 | Heilprin | Rocky Mountain sub-region | Animals | 2 |
| 1887 | Brendel | Prairie flora | Plants | 1 |
| 1889 | Ridgway | Rocky Mountain or middle district | Birds | 2 |

*Pacific or California division.*—This name has been very generally applied to the Pacific coast region of the United States. It was first recognized by the botanist De Candolle in 1820. Pickering, in 1830, named it the Californian flora, but knowing little or nothing of the Sierra Nevada, and believing the Rocky Mountains to be the only mountain system of importance in North America, extended its eastern boundary to that range. In this way he was followed by the botanist Hinds, in 1843; by the conchologists, Amos Binney, in 1851, and Woodward, in 1856. Agassiz, in 1854, was first to fix its eastern limit at the Sierra Nevada and Cascade mountains, where it has been permitted to rest. Its north and south boundaries have undergone considerable fluctuations.

The extent to which the Pacific or Californian region has been recognized will appear from the following table:*

| Date. | Author. | Name given to region. | Based on – | Rank. |
|---|---|---|---|---|
| 1820 | De Candolle ...... | West coast of temperate North America.......... | Plants........ | 1 |
| 1830 | Pickering ........ | Californian flora.................................. | ....do ......... | 2 |
| 1843 | Hinds ............ | Californian region................................. | ....do ......... | 1 |
| 1848 | Frankenheim..... | California .......................................... | ....do ......... | 2 |
| 1851 | Binney (A.) ...... | Pacific region....................................... | Mollusks ..... | 1 |
| 1854 | Agassiz .......... | Californian fauna.................................. | Animals ...... | 3 |
| 1856 | Woodward ....... | Californian province.............................. | Mollusks ..... | 1 |
| 1859 | Le Conte ......... | Western district.................................... | Insects ....... | 1 |
| 1859 | Cooper............ | Nevadian province†................................ | Forests ....... | 1 |
| 1863 | Binney (W. G.) ... | Pacific province .................................... | Mollusks ..... | 1 |
| 1866 | Baird.............. | Western province .................................. | Birds .......... | 1 |
| 1866 | Grisebach ........ | Californian region................................. | Plants ........ | 1 |
| 1873 | Cope............... | Pacific region....................................... | Reptiles and batrachians. | 2 |
| 1874 | Porter............ | ......do ............................................... | Plants ........ | 1 |
| 1876 | Wallace .......... | Californian sub-region........................... | Animals ...... | 2 |
| 1878 | Allen.............. | Western province ................................. | ...do .......... | 2 |
| 1883 | Packard.......... | ......do ............................................... | ...do .......... | 1 |
| 1883 | Jordan ........... | Pacific region....................................... | Mollusks ..... | 3 |
| 1884 | Drude ............ | Californian district ............................... | Plants......... | 2 |
| 1886 | Hartlaub ......... | Californian region ................................. | Birds .......... | 2 |
| 1887 | Heilprin.......... | Californian sub-region........................... | Animals ...... | 2 |
| 1887 | Brendel........... | Californian flora................................... | Plants ........ | 1 |
| 1889 | Ridgway ......... | Pacific district...................................... | Birds .......... | 2 |

*Engler's "California Coast Province" is not included in this table, because it consists only of the narrow strip of land between the Coast Range and the Pacific.

† Named from the Sierra Nevada—not the State of Nevada.

### AUSTRO-RIPARIAN OR LOUISIANIAN DIVISION.

(South Atlantic and Gulf States.)

Latreille, as early as 1817, called attention to the difference in the insect fauna in Carolina and Georgia from that of Pennsylvania and New York, and in his division of the earth into circum-polar zones ran the boundary line between these fauna at latitude 36°. The difference in the flora of the South Atlantic and Gulf States from that of the Northern States was recognized by the Danish botanist Schouw as early as 1822 in the "Realm of Magnolias or Pursh's Realm," which he then proposed for the region between the parallels of 30° and 36° north latitude. Thirty-four years later (in 1856) the northern boundary of the same area was run by America's greatest botanist, Dr. Asa Gray, along the parallel of 36° 30′, only half a degree from Schouw's line. The first zoölogist to recognize this region was the elder Binney, who died in 1847. His posthumous work on "Terrestrial Air-Breathing Mollusks," published in 1851, describes it under the name "Tertiary Region of the Atlantic Coast and the Gulf of Mexico." The elder Agassiz recognized it in 1854 as one of his seven primary regions, nam-

ing it the Louisianian fauna. Later writers, except Cope, have considered it a sub-division of the Eastern forest region. Cope restored it to primary rank in 1873 and named it the Austro-riparian region.

The extent to which this region has been recognized will appear from the following table:

| Date. | Author. | Name given to region. | Based on— | Rank. |
|---|---|---|---|---|
| 1817 | Latreille | Super-tropical climate | Insects | 1 |
| 1822 | Schouw | Realm of magnolias | Plants | 1 |
| 1836 | Meyen | Sub-tropical zone | ....do | 1 |
| 1837 | Martius | Mississippi-Floridian realm | ....do | 1 |
| 1838 | Berghaus | Realm of magnolias | ....do | 1 |
| 1851 | Binney (A.) | Tertiary region of Atlantic and Gulf coasts | Mollusks | 2 |
| 1853 | Schmarda | Middle American realm | Animals | 1 |
| 1854 | Agassiz | Louisianian fauna | ....do | 3 |
| 1856 | Gray | Southern States | Plants | 1 |
| 1859 | Le Conte | Southern province | Insects | 2 |
| 1859 | Cooper | Carolinian and Mississippian | Forests | 2 |
| 1863 | Binney (W. G.) | Southern region | Mollusks | 2 |
| 1866 | Baird | Southern sub-division | Birds | 2 |
| 1866 | Verrill | Louisianian fauna | ....do | 2 |
| 1871 | Allen | ......do | ....do | 3 |
| 1873 | Cope | Austro-riparian region | Reptiles and batrachians | 2 |
| 1874 | Porter | Southern district | Plants | 2 |
| 1883 | Jordan | ......do | Mollusks | 4 |
| 1884 | Sargent | Coast pine region | Forests | 2 |
| 1890 | Merriam | Austro-riparian region | Animals and plants. | 2 |

### SONORAN DIVISION.

The term "Sonoran region" has been applied by Cope and others to an important life area which enters the southwestern part of the United States from the table-land of Mexico. It was first recognized by a botanist, Richard Brinsley Hinds, R. N., surgeon to H. M. S. *Sulphur*, who published a description of it in 1843 under the name "The Chihuahua Region." He defined it as extending south to the tropic, west to the Gulf of California and the Colorado River, north to the prairie region of the United States, and separated on the east from the Gulf of Mexico by a northward extension of the Central American region along the lowlands bordering the coast. Prof. Baird (in 1866) stated that along the valleys of the Rio Grande and Gila the fauna of the Central province "is greatly mixed up with the peculiar fauna of northern Mexico, which, as far as its summer birds indicate, is almost entitled to be considered as a fourth main province."

The extent to which this region has been recognized will appear from the following table:

| Date. | Author. | Name given to region. | Based on— | Rank. |
|---|---|---|---|---|
| 1843 | Hinds | Chihuahuan | Plants | 1 |
| 1859 | Le Conte | Southwestern and south-southwestern provinces. | Insects | 2 |
| 1859 | Cooper | Arizonian region | Forests | 2 |
| 1861 | ...do | Arizonian and Chihuahuan regions | ...do | 2 |
| 1866 | Baird | No name given | Birds | 2 |
| 1870 | Brown | New Mexican region | Forests | 2 |
| 1873 | Cope | Sonoran | Reptiles and batrachians. | 2 |
| 1874 | Porter | Cactus region | Plants | 1 |
| 1878 | Dyer | Mexico-Californian flora | ...do | 2 |
| 1882 | Engler | Aztec province | ...do | 3 |
| 1884 | Sargent | Mexican forest region | Forests | 1 |
| 1884 | Drude | North Mexico and Texas district | Plants | 2 |
| 1887 | Heilprin | Sonoran transition region | Animals | (?) |
| 1890 | Merriam | Sonoran province | Animals and plants. | 1 |

PENINSULA OF LOWER CALIFORNIA.

That the fauna and flora of the peninsula of Lower California, or any part of it, differs radically from that of the State of California immediately on the north was pointed out almost simultaneously by Baird and Le Conte in 1859. Baird stated that the fauna of its southern extremity, as determined by collections of its mammals, birds, and reptiles, "is almost identical with that of the Gila River, and to a certain extent with that of the Rio Grande," but differs wholly from that of Upper California. In accordance with these facts he afterwards (in 1866) made Lower California a sub-division of the central province. Later in the same year (1859) Le Conte stated that a few species of insects from Cape St. Lucas, "though all new, indicate a greater resemblance to the fauna of the Lower Colorado than to that of maritime California; this province may therefore be found eventually to belong to the interior district."

Cooper (in 1861) proposed the name *Uchitan* for the forest flora of Lower California, and regarded it as a sub-division of his Nevadian (=Californian) province. Grisebach also, in mapping the plant regions of the world in 1866, included the peninsula in his Californian region, but afterwards (in 1872) transferred it to the interior or prairie region.

Cope, in 1873, raised Lower California to primary rank, basing his action on a study of its reptiles and batrachians. Wallace, in 1876, placed it in the central province without sub-division. Packard, in 1883, followed Baird and Grisebach in regarding the southern part of the peninsula as a sub-division of the central province, while the northern part was assigned to the Pacific province. Drude, in 1884, divided it transversely in two nearly equal plant areas, placing the northern

half in his "North Mexico and Texas district," and the southern half in his tropical "Mexican District." Hartlaub and Newton, in 1886, placed the entire peninsula in their Mexican region, and Heilprin, in 1887, in his Sonoran transition region.

The way in which Lower California has been regarded by different writers is shown in the following table:*

| Date. | Author. | How regarded. | Study based on— | Rank. |
|---|---|---|---|---|
| 1837 | Martins | As part of his Mexican extra-tropical realm | Plants | 0 |
| 1838 | Berghaus | As part of his Mexican realm ("Jacquin's realm") | ....do | 0 |
| 1843 | Hinds | As part of his Californian region | ....do | 0 |
| 1845 | Berghaus | As part of his tropical province | Mammals | 0 |
| 1854 | Agassiz | As part of his Californian fauna | Animals | 0 |
| 1856 | Woodward | As part of his Californian province | Mollusks | 0 |
| 1859 | Baird | As a sub-division of his middle province | Birds | 2 |
| 1859 | Le Conte | As part of his central district | Insects | 0 |
| 1861 | Cooper | As a sub-division of his Nevadian [=Californian] province. | Forests | 2 |
| 1866 | Grisebach | As part of his Californian region | Plants | 0 |
| 1870 | Brown | As part of his Colorado desert district | Forests | 0 |
| 1872 | Grisebach | As part of his prairie region | Plants | 0 |
| 1873 | Cope | As an independent region | Reptiles and batrachians. | 2 |
| 1876 | Wallace | As part of his California sub-region | Animals | 0 |
| 1882 | Engler | As part of his Aztec province | Plants | 0 |
| 1883 | Packard | As part of his central province | Animals | 0 |
| 1884 | Drude | As part of his Mexican district | Plants | 0 |
| 1886 | Hartlaub | ......do | Birds | 0 |
| 1887 | Heilprin | As part of his Sonoran transition region | Animals | 0 |
| 1890 | Merriam | As a division of his Sonoran province | Animals and plants. | 2 |

* In the few cases in which the peninsula has been divided, the assignment here given relates to the southern extremity.

SOUTHERN FLORIDA.

The large number of tropical forms of life inhabiting southern Florida early led to its separation from the rest of the Atlantic region by writers on the distribution of animals and plants. Lesson (in 1831) placed it along with Mexico in his south temperate zone. Hinds (in 1843), recognizing its Antillean affinities, placed the southern extremity of the peninsula (south of latitude 27°) in his West India region.

The extent to which southern Florida has been recognized as faunally and florally distinct from the rest of the United States is shown in the following table:

| Date. | Author. | Name given to region. | Based on— | Rank. |
|---|---|---|---|---|
| 1831 | Lesson | [Florida division of south temperate zone] | Birds | 0 |
| 1843 | Hinds | [Florida division of West India region] | Plants | 0 |
| 1851 | Binney (A.) | Peninsula of Florida | Mollusks | 2 |
| 1858 | Cooper | Floridian region | Forests | 2 |
| 1859 | Le Conte | Sub-tropical province | Insects | 2 |
| 1866 | Baird | [Florida division of Atlantic region] | Birds | 3 |
| 1866 | Verrill | [Florida division of West Indian region] | do. | 0 |
| 1870 | Brown | Florida sub-region | Forests | 2 |
| 1871 | Allen | Floridian fauna | Birds | 3 |
| 1873 | Cope | Floridian district | Reptiles and batrachians. | 3 |
| 1874 | Porter | Florida region | Plants | 1 |
| 1883 | Packard | [Florida division of Antillean region] | Animals | 0 |
| 1883 | Jordan | [Florida division of neo-tropical province] | Mollusks | 0 |
| 1884 | Sargent | Semi-tropical forest of Florida | Forests | 2 |
| 1887 | Drude | [Florida division of Antillean region | Plants | 0 |
| 1887 | Reichenow | [Florida division of South American region] | Birds | 0 |
| 1887 | Brendel | South Florida [Antillean] | Plants | 1 |
| 1888 | Schwarz | [Florida division of Antillean region] | Insects | 0 |
| 1890 | Merriam | [Florida division of Antillean sub-region] | Animals and plants. | 3 |

ANTILLEAN DIVISION.

The fauna and flora of the West Indies have been variously interpreted by different writers, some placing the region in South America, others in Mexico, and others still raising it to independent rank.

In 1822, Schouw, in mapping the plant areas of the world, placed it in his "Jacquin's realm or realm of cactuses and peppers." Subsequently, however (in 1833), he gave it independent primary rank, naming it "Swartz's realm." Martius, in 1837, was first to bestow the name "Antillean realm" upon this region, which he regarded as a division of primary rank, comprising the West Indies and adjacent coasts of South and Central America. The same arrangement was retained in his lecture on floral realms in 1865.

The way in which the West Indies have been regarded by different writers is shown in the following table:

| Date. | Author. | How regarded. | Based on— | Rank. |
|---|---|---|---|---|
| 1820 | De Candolle ...... | As an independent region ........................ | Plants ........ | 1 |
| 1822 | Schouw........... | As part of his realm of cactuses and peppers (Mexican). | ....do ......... | 0 |
| 1830 | Pickering......... | As part of his American inter-tropical region ... | ....do ......... | 0 |
| 1831 | Lesson............ | As part of his equatorial zone .................... | Birds ......... | 0 |
| 1833 | Schouw ........... | As an independent realm (Swartz's realm)........ | Plants ........ | 1 |
| 1835 | De Candolle ...... | As an independent region ........................ | ....do ......... | 1 |
| 1837 | Martius ......... | As an independent realm (Antillean realm)........ | ....do ......... | 1 |
| 1838 | Berghaus......... | As an independent realm (Swartz's realm)........ | ....do ......... | 1 |
| 1841 | Pompper.......... | As part of his north warm zone .................. | Animals ...... | 0 |
| 1843 | Hinds ............ | As an independent realm (West Indian region) ... | Plants ........ | 1 |
| 1845 | Berghaus......... | As part of his tropical province .................. | Mammals..... | 0 |
| 1846 | Wagner .......... | As part of his tropical American province......... | ....do ......... | 0 |
| 1854 | Agassiz .......... | As a sub-division of his Central American region. | Animals ...... | 3 |
| 1856 | Woodward ....... | As an independent province (Antillean province). | Mollusks ..... | 1 |
| 1858 | Sclater ........... | As a part of his neo-tropical region ............... | Birds ......... | 0 |
| 1866 | Baird............. | As a primary region (West Indian region)........ | ....do ......... | 1 |
| 1866 | Grisebach ....... | ......do ........................................... | Plants ........ | 1 |
| 1868 | Huxley........... | As a part of his Austro-Columbian region ........ | Animals...... | 0 |
| 1870 | Brown............ | As an independent province (Antillean province). | Forests ....... | 1 |
| 1875 | Sclater ........... | As an independent sub-region (Antillean sub-region) | Birds ......... | 2 |
| 1876 | Wallace .......... | ......do ........................................... | Animals...... | 2 |
| 1882 | Engler ........... | As an independent province ...................... | Plants ........ | 3 |
| 1883 | Packard .......... | As an independent region (Antillean region) ..... | Animals ...... | 1 |
| 1883 | Jordan............ | As part of his neo-tropical province ............. | Mollusks ..... | 0 |
| 1884 | Drude ............ | As an independent region (Antillean district) .... | Plants ........ | 2 |
| 1886 | Hartlaub ........ | As an independent region (Antillean region) ..... | Birds ......... | 2 |
| 1887 | Heilprin.......... | As a sub-division of his neo-tropical region ...... | Animals ...... | 2 |
| 1887 | Reichenow ....... | As part of his South American region............ | Birds ......... | 0 |
| 1890 | Merriam.......... | As a division of his tropical province............ | Animals and plants. | 2 |

NORTHWEST COAST DIVISION.

In 1843, Hinds, in maping the plant regions of the world, proposed a "northwest American region" for the area west of the Rocky Mountains, north of the Columbia River, and south of latitude 68° north. Agassiz, in his paper on the zoölogical regions of the earth (1854), gave the name "Northwest Coast Fauna" to essentially the same area (shown on his map as extending along the Pacific from northern California to the base of the Unalaskan Peninsula).

In 1859, Le Conte, who based his studies on Coleoptera, spoke of this region as the "Hyperborean province" of the Pacific district; and the same year Cooper, writing of the forest regions, described it as the "Caurine province." W. G. Binney, in 1873, mentioned it as the "Oregonian division" of the Pacific province; Engler, in 1882, as the "Kaloschen zone;" Drude, in 1884, as the "Columbian district;" Nelson, in 1887, as the "Sitkan district;" Brendel, in 1887, as the "North Pacific province."

### PRAIRIE DIVISION.

A few botanists, influenced by the widely different aspects of nature resulting from the presence or absence of forests, have recognized a "Prairie region," as one of the great floral divisions of North America. It was first proposed by Pickering, in 1830. Pickering named it the "Louisianian flora," and gave its boundaries as the Mississippi on the east and the Rocky Mountains on the west. Hinds described it, in 1843, as "a peculiar tract inclosed by the vast forests of North America." He named it the "Prairie region," and said it extended "from within a hundred miles of the west bank of the Mississippi to the Rocky Mountains, stretching north to 54° north latitude, and again only bounded on the south by the wooded country of the Texas and the Mexican Sea."

Cooper, in his paper on the distribution of forests (in 1859), named it the Campestrian province. It was recognized by Brown in 1870, by Porter in 1874, and by Engler in 1882.

### RECAPITULATION.

It is seen that a number of zoölogists and botanists, basing their studies on widely different groups, and as a rule ignorant of the writings of their predecessors, have agreed in the main in the recognition of at least seven life areas in extra-tropical North America, namely: (1) An Arctic area north of the limit of tree growth; (2) a boreal trans-continental coniferous forest region; (3) an Atlantic or Eastern wooded region stretching westward from the Atlantic to the Great Plains; (4) a central or middle region, reaching from the plains to the Sierra Nevada and Cascade Mountains; (5) a Pacific or California division, covering the area between the east base of the Sierra and the Pacific Ocean; (6) a Louisianian or Austro-riparian division, comprising the South Atlantic and Gulf States south of latitude 36°; (7) a Sonoran division, occupying the high table-land of Mexico and stretching northward over the dry interior far enough to include the southern parts of California, Nevada, Arizona, New Mexico, and Texas.

With or without reference to the above principal divisions, it has been recently the custom of zoölogists, particularly ornithologists, to sub-divide the eastern United States and Canada into several minor areas or "faunas," as follows: (*a*) Floridian; (*b*) Louisianian; (*c*) Carolinian; (*d*) Alleghanian; (*e*) Canadian; (*f*) Hudsonian; and (*g*) Arctic. Of these the Canadian and Hudsonian form a part of the "Boreal" region above mentioned, and the Floridian and Louisianian together make up the "Austro-riparian" division, leaving only the Carolinian and Alleghanian for the so-called "Eastern province" to rest on. The true relations of these zones will be explained later.

LIFE REGIONS AND ZONES OF NORTH AMERICA

In a communication I had the honor to lay before this society two years ago (December 4, 1889),* I stated that the Hudsonian and Canadian zones of the East belong to the Boreal region, and extend completely across the continent, and that the desert areas of the West belong to the Southern or Sonoran region. The pine plateau (*Pinus ponderosa*) of Arizona and other parts of the West was "shown to consist of a mixture of Boreal and Sonoran types. - - - In other words, it is neutral territory" (*North American Fauna*, No. 3, September, 1890, p. 20). I remarked further that the Carolinian fauna "is suffused with southern forms, and the Alleghanian seems to be neutral ground" (*Ibid.*, p. 18), thus implying that the "neutral" or pine-plateau zone of Arizona is the western equivalent of the "Alleghanian Fauna" of the East.

In a subsequent publication (*North American Fauna*, No. 5, August, 1891) I went a step further, defining the treeless parts of the "Neutral or Transition zone," and characterizing an "Upper Sonoran zone," as distinguished from the Lower or True Sonoran; but nothing was said as to the relations of these zones with those long recognized in the East.

The time has now arrived, however, when it is possible to correlate the Sonoran zones of the West with corresponding zones in the East, as was done two years ago in the case of the Boreal zones, and as was intimated in the case of the Neutral or Transition zone. It can now be asserted with some confidence not only that the Transition zone of the West is the equivalent of the Alleghanian of the East, but also that the Upper Sonoran is the equivalent of the Carolinian, and the Lower Sonoran of the Austro-riparian, and that each can be traced completely across the continent. Thus, all the major and minor zones that have been established in the East are found to be uninterruptedly continuous with corresponding zones in the West, though their courses are often tortuous, following the lines of equal temperature during the season of reproduction, which lines conform in a general way to the contours of altitude, rising with increased base-level and falling with increased latitude.

The Boreal region extends obliquely across the entire continent from New England and Newfoundland to Alaska and British Columbia, and from about latitude 45° north to the Polar Sea, conforming in general direction to the trend of the northern shores of the continent. It recedes to about latitude 54° on the plains of the Saskatchewan, and gives off three long arms or chains of islands, which reach far south along the three great mountain systems of the United States—an eastern arm in the Alleghanies, a central arm in the Rocky Mountains,

* Since published in my report on the "Results of a Biological Survey of the San Francisco Mountain region in Arizona," *N. Am. Fauna*, No. 3, September 11, 1890.

and a western arm in the Cascades and Sierra Nevada. The latter at its northern base occupies the entire breadth of the Pacific Coast region from the eastern slope of the mountains to the sea, but in passing southward bifurcates, the main fork following the lofty Cascade and Sierra ranges to about latitude 36°; the other following the coast, gradually losing its distinctive characters and becoming invaded with Sonoran forms until it disappears a little north of San Francisco.

The following genera of mammals belong exclusively to the Boreal region, none of them ranging south beyond the Transition zone:

| | | | |
|---|---|---|---|
| Cervus. | Arctomys. | Cuniculus. | Latax. |
| Rangifer. | Aplodontia. | Zapus. | Gulo. |
| Alce. | Evotomys. | Erethizon. | Mustela. |
| Mazama. | Phenacomys. | Lagomys. | Neurotrichus(?). |
| Ovibos. | Myodes. | Thalarctos. | Condylura. |

In addition to the above, the following genera are clearly of Boreal origin, although reaching and in some cases penetrating parts of the Sonoran region:

| | | | |
|---|---|---|---|
| Ovis. | Castor. | Vulpes. | Putorius. |
| Bison.* | Arvicola. | Ursus. | Sorex. |
| Tamais. | Fiber. | Lutreola. | |

Besides the genera here enumerated, the following sub-genera belong to the Boreal region: *Tamiasciurus* (containing the red or spruce squirrels), *Mynomes* and *Chilotus* (field-mice or voles, of which *Mynomes* reaches south a little beyond the Transition zone), *Teonoma* (the bushy-tailed wood-rats), and *Neosorex* and *Atophyrax* (subgenera of shrews).

The Boreal region is made up of two principal divisions, both circumpolar: (1) An Arctic division, above the limit of tree growth; and (2) a Boreal Coniferous Forest division.

### ARCTIC MAMMALS.

(Found above the limit of trees and all circum-polar.)

A. *Exclusively Arctic.*

| | |
|---|---|
| Eskimo | *Homo.* |
| Polar bear | *Thalarctos maritimus.* |
| Barren ground bear | *Ursus richardsoni.* |
| Musk ox | *Ovibos moschatus.* |
| Barren ground caribou | *Rangifer grœnlandicus.* |
| Arctic fox | *Vulpes lagopus.* |
| Arctic hare | *Lepus glacialis.* |
| Lemming | *Myodes obensis.* |
| Lemming | *Cuniculus torquatus.* |
| Arctic red-backed mouse | *Evotomys rutilus.* |
| Parry's spermophile | *Spermophilus empetra.* |

*The faunal position of the genus *Bison* is not so certain as in the case of the other genera here mentioned, though both the American and the European species seem to be of Boreal origin.

B. *Common to Arctic and Hudsonian.*

| | |
|---|---|
| Wolverine | *Gulo luscus.* |
| Gray wolf | *Canis griseus.* |
| Ermine | *Putorius erminea.* |

The Boreal Coniferous Forest division may be subdivided into at least two trans-continental zones: (*a*) Hudsonian and (*b*) Canadian; and a third or "Timber-line zone" may be differentiated from the Hudsonian proper. In speaking of the divisions of the Boreal region on high mountains it is customary to add the word alpine to the name of the division; thus, Arctic-alpine, Hudsonian-alpine, and so on.

MAMMALS OF THE BOREAL ZONE.

(The letter *a* indicates that the species is known only from mountains, or is in an alpine form.)

**Cervus canadensis.**
**Rangifer caribou.**
**Alce americanus.**
**Mazama montana.**
**Ovis canadensis.**
**dalli.**
**Sciuropterus volans sabrinus.**
**Sciurus fremonti.**
**mogollonensis (*a*).**
**hudsonicus.**
**californicus (*a*).**
**vancouverensis.**
**richardsoni.**
**douglassi.**
**Tamias cinereicollis (*a*).**
**obscurus (*a*).**
**senex (*a*)**
**speciosus (*a*).**
**townsendi.**
**umbrinus (*a*).**
**quadrivittatus (*a*).**
**amœnus (*a*).**
**luteiventris (*a*).**
**borealis.**
**neglectus.**
**Spermophilus lateralis.**
**castanurus (*a*).**
**chrysodeirus (*a*).**
**cinerascens.**
**armatus (*a*).**
**beldingi (*a*).**
**empetra.**
**kodiacensis.**
**columbianus.**
**Arctomys caligatus (*a*).**
**dacota (*a*).**
**flaviventer (*a*).**
**Aplodontia major (*a*).**
**rufa.**
**Sitomys americanus arcticus.**
**austerus.**
**Neotoma cinerea drummondi.**
**Phenacomys borealis.**
**celatus.**
**intermedius.**
**latimanus.**
**longicaudus.**
**orophilus (*a*).**
**ungava.**
**Evotomys californicus.**
**occidentalis.**
**Evotomys idahoensis.**
**carolinensis (*a*).**
**dawsoni.**
**galei (*a*).**
**gapperi.**
**brevicaudus.**
**Arvicola alticolus (*a*).**
**drummondi.**
**nanus (*a*).**
**oregonus.**
**mordax.**
**longicaudus.**
**townsendi.**
**macropus.**
**xanthognathus.**
**Myodes obensis.**
**Cuniculus torquatus.**
**Zapus hudsonius.**
**Erethizon dorsatus.**
**epixanthus.**
**Lagomys princeps (*a*).**
**schisticeps (*a*).**

MAMMALS OF THE BOREAL ZONE.—Continued.

| | |
|---|---|
| Lepus americanus. | Sorex monticolus (*a*). |
| bairdii (*a*). | pacificus. |
| washingtoni. | richardsoni. |
| Lynx canadensis. | sphagnicolus. |
| Ursus americanus. | suckleyi. |
| horribilis. | trowbridgei. |
| Putorius culbertsoni. | vagrans. |
| longicauda. | similis (*a*). |
| Mustela americana. | albibarbis. |
| caurina. | palustris. |
| pennanti. | hodrodromus. |
| Sorex belli. | Condylura cristata. |
| dobsoni (*a*). | Vesperugo noctivagans. |
| fosteri. | Atalapha cinerea. |
| idahoensis. | |

The Sonoran region as a whole stretches across the continent from Atlantic to Pacific, covering nearly the whole country south of latitude 43° and reaching northward on the Great Plains and Great Basin to about latitude 48°. It is invaded from the north by three principal intrusions of boreal forms along the three great mountain systems already mentioned; while to the southward it occupies the great interior basin of Mexico and extends into the tropics along the highlands of the interior. It covers also the peninsula of Lower California, the southern part of which seems entitled to rank as an independent subdivision.

The following genera belong exclusively to the Sonoran region (as distinguished from the boreal), none of them ranging north beyond the transition zone. Those preceded by the letter *T* are intrusions from the tropical region.

| | | | |
|---|---|---|---|
| *T* Didelphis. | Geomys. | Bassariscus. | Euderma. |
| *T* Tatusia. | Dipodomys. | *T* Nasua. | Antrozous. |
| *T* Dicotyles. | Perodipus.* | Conepatus. | Nycticejus. |
| Reithrodontomys.† | Microdipodops. | Spilogale. | *T* Molossus. |
| Onychomys. | Perognathus. | Notiosorex. | *T* Nyctinomus. |
| Oryzomys. | Heteromys. | Scalops. | *T* Otopterus. |
| Sigmodon. | Urocyon. | Corynorhinus. | |

* The generic name *Perodipus* was proposed in 1867 by Fitzinger for the 5-toed kangaroo rats (*Sitzungsber. math. nat.* Classe, K. *Akad. Wiss. Wien*, 1867, LVI, p. 126), thus ante-dating by twenty-three years the name *Dipodops* proposed by the writer for the same type in 1890 (*North Am. Fauna*, No. 3, September, 1890, p. 72). Both generic names were based on *Dipodomys agilis* of Gambel, from Los Angeles, Cal.

† The generic name *Reithrodontomys* was proposed by Giglioli in 1873 (*Richerche intorno alla Distribuzione Geografica Generale*, Roma, 1873, p. 160), and ante-dates *Ochetodon* of Coues.

In addition to the above, the following genera seem to be of Sonoran or austral origin, although reaching and in some cases penetrating a considerable distance into the boreal region:

| | | | |
|---|---|---|---|
| Cariacus. | Neotoma. | Mephitis. | Blarina. |
| Antilocapra. | Thomomys. | ? Felis. | Atalapha. |
| Cynomys. | ? Procyon. | Lynx. | Vesperugo. |
| Sitomys.* | Taxidea. | Scapanus. | Vespertilio. |

The genera *Sitomys*, *Mephitis*, *Lynx*, *Atalapha*, *Vesperugo*, and *Vespertilio* range well north in the Boreal zone, where each is represented by a single species. In the Sonoran zone, on the other hand, these same genera reach their maximum development and are represented by numerous species.

Besides the genera above enumerated, a number of sub-genera belong to the Sonoran region. Among these are *Neosciurus* and *Parasciurus* (subgenera of *Sciurus*), *Xerospermophilus*,† *Ammospermophilus*,‡ and *Ictidomys* (sub-genera of *Spermophilus*), *Pitymys*, *Pedomys*, and *Neofiber* (sub-genera of *Arvicola*), and *Chætodipus* (a sub-genus of *Perognathus*, which is almost entitled to rank as a full genus).

The Sonoran region may be divided by temperature into two principal trans-continental zones, (*a*) Upper Sonoran, and (*b*) Lower Sonoran; § and each of these in turn may be sub-divided into arid and humid divisions.

The gray fox, *Urocyon*, ranges over both Upper and Lower Sonoran from Atlantic to Pacific; and pocket gophers of the genus *Geomys* inhabit both these divisions on the Great Plains and in the Mississippi Valley, and range east to the Atlantic in the Austro-riparian zone.

Both divisions of the Lower Sonoran are inhabited by the trans-continental genera *Reithrodontomys*, *Sigmodon*, *Corynorhinus*, *Nyctinomus*, *Otopterus*, *Neotoma*, and *Spilogale*, though in the west the two last mentioned range through the Upper Sonoran also.

The humid Lower Sonoran or Austro-riparian is a division of much importance. It begins on the Atlantic seaboard at the mouth of Chesapeake Bay and stretches thence southwesterly, embracing the alluvial lands of the South Atlantic and Gulf States below what geologists

* The generic name *Hesperomys* being untenable, Allen has recently substituted for it the name *Vesperimus* proposed by Coues as a subgenus in 1874 (*Bull. Am. Mus. Nat. Hist.*, June, 1891, III, No. 2, pp. 291–297). *Vesperimus* is ante-dated by *Sitomys* of Fitzinger, proposed in 1867, and based on Gapper's *Cricetus myoides* from Lake Simcoe, Ontario, Canada (*Sitzungsber. math. nat. Classe, K. Akad. Wiss. Wien.* 1867, LVI, p. 97). Gapper's *Cricetus myoides* is the common white-footed mouse of southern Ontario and northern New York, which therefore becomes the type of the genus.

† *Xerospermophilus*, sub-gen. nov., proposed for *Spermophilus mohavensis* (type) and the allied species of the *S. spilosoma* group.

‡ *Ammospermophilus*, sub-gen. nov., proposed for *Spermophilus leucurus* (type) and allied species.

§ The great Lower Sonoran Zone may be split lengthwise (in an east and west direction) into two belts which have not yet been thoroughly differentiated.

know as the "fall line," rising in the Mississippi bottom as far as the junction of the Ohio with the Mississippi, and following the former in a narrow strip to the point where it receives the Wabash. On the west side of the Mississippi it crosses Arkansas, reaches southern Missouri and southeastern Kansas, and spreads out over Indian and Oklahoma Territories and Texas, where it loses its moisture and merges insensibly into the arid Sonoran. *Oryzomys* and *Nycticejus* are distinctive Austroriparian genera. Six other genera (*Neotoma*, *Reithrodontomys*, *Geomys*, *Spilogale*, *Nyctinomus*, and *Corynorhinus*), which in the region east of the Mississippi seem to be restricted to this division, have a more extended range in the west. The cotton rat (*Sigmodon*), another characteristic Austro-riparian genus, has a very limited range in the arid Sonoran.

The arid Lower Sonoran extends westerly from the humid Sonoran to the Pacific, covering southern New Mexico and Arizona south of the plateau rim (sending a tongue up the Rio Grande to a point above Albuquerque), the west side of which it follows northerly to the extreme northwestern corner of Arizona and the southwestern corner of Utah (where it is restricted to the valley of the lower Santa Clara, or St. George Valley), and thence westerly across Nevada, reaching northerly to Pahranagat, Oasis, and Owens valleys, and thence curving southwesterly, following the eastern base of the Sierra Nevada, Tehachapi, and Tejon Mountains, and covers the whole of the Mohave and Colorado deserts and all the rest of southern California except the mountains. It sends an arm southward over most of the peninsula of Lower California, and another northward covering the San Joaquin and Sacramento valleys. The distinctive mammals of the arid Lower Sonoran are kangaroo rats of the genus *Dipodomys*, pocket-mice of the sub-genus *Chætodipus*, and spermophiles of the sub-genera *Xerospermophilus* and *Ammospermophilus*.

The peninsula of Lower California is a sub-division of the arid Lower Sonoran zone. Not a single genus of land mammal or bird is restricted to it and but two peculiar species of mammals have been described. The peculiar birds are more numerous, but with few exceptions are only sub-specifically separable from those of neighboring parts of the United States and Mexico. They may be classed in two categories: (1) mountain forms derived from the North (of Boreal or Transition origin); and (2) lowland forms derived from the contiguous plains (of Sonoran, or in one instance, sub-tropical origin). As would be expected from the character of the country, the great majority are subspecies of well known Sonoran forms, with the addition of a small number of peculiar species belonging to Sonoran genera. But a single subtropical bird is known, namely, *Dendroica bryanti castaneiceps*, and it is restricted to the mangrove lagoons.

The presence of this sub-tropical bird in the narrow coast lagoons is in complete accord with the vegetation of the coast strip, which, as Mr.

T. S. Brandegee tells us, is sub-tropical.* This indicates the presence of a narrow coast belt similar to that of southern Florida, but of less extent. It is possible that *Basilinna xantusi* is sub-tropical rather than Sonoran, but the details of distribution of the genus are not well known.

Among reptiles, about 25 peculiar species of snakes and lizards are believed to be restricted to the peninsula, but no peculiar genus is known. Three of the genera are tropical, and nine are arid Lower Sonoran.

In addition to the peculiar species and sub-species of the peninsula, many characteristic arid Lower Sonoran forms of mammals, birds, reptiles, insects, and plants abound. Among the latter may be mentioned the highly distinctive Sonoran desert brush, *Larrea mexicana* and *Krameria parvifolia*.

Cope includes the whole peninsula in his Lower California region, but other writers restrict the peculiar fauna and flora to the end of the peninsula south of the north foot of the mountains between La Paz and Todos Santos. Bryant states: "There is no more sharply defined faunal and floral area that occurs to me now, excepting that of islands, than is embraced in the region above defined," † but he omits to name the forms by which it is characterized. It is evident however that the peculiar fauna of the peninsula of Lower California entitles it to rank as a minor sub-division of the Lower Sonoran zone. It is in effect an insular fauna of recent origin, bearing the same relation to that of the mainland as do several of the adjacent islands.

The humid division of the Upper Sonoran comprises the area in the eastern United States commonly known as the Carolinian fauna. The opossum (*Didelphis*) here finds its northern limit, as do the so-called pine-mouse (sub-genus *Pitymys*) and the Georgian bat (*Vesperugo georgianus*). Before reaching the one hundredth meridian this area gradually loses its moisture and spreads out over the Great Plains as the arid or true Upper Sonoran, reaching an altitude of about 4,000 feet along the east foot of the Rocky Mountains in the latitude of Colorado, and sending a tongue northward along the Missouri obliquely through North Dakota and into eastern Montana. Another sub-division of the arid Upper Sonoran occupies the greater part of the Great Basin between the Rocky Mountains and the High Sierra, reaching northerly from the upper border of the Lower Sonoran to and including the plains of the Columbia and Snake rivers. Another part of noteworthy extent is a narrow belt encircling the interior basin of California—the valley of the Sacramento and San Joaquin rivers—and a branch of the same along the coast between Monterey and the Santa Barbara plain.

* Brandegee, *Proc. Calif. Acad. Sci.*, 1891, 2d ser., III, 110.

† Walter E. Bryant in *Zoe*, Oct., 1891, II, No. 3, 186. See also his important "Catalogue of the Birds of Lower California," *Proc. Calif. Acad. Sci.*, 1889, 2d ser., II, 237–320.

The following genera of mammals find their northern limit in the arid Upper Sonoran zone: *Perodipus*, *Microdipodops*, *Perognothus*, *Onychomys*, *Spilogale*, *Urocyon*, *Bassariscus*, and *Antrozous*.

Interposed between the Boreal and Sonoran regions throughout their numerous windings and interdigitations, is the Neutral or Transition zone. The humid division of this zone, known as the Alleghanian fauna,* covers the greater part of New England (except Maine and the mountains of Vermont and New Hampshire) and extends westerly over the greater part of New York, southern Ontario, and Pennsylvania, and sends an arm south along the Alleghanies all the way across the Virginias, Carolinas, and eastern Tennessee, to northern Georgia and Alabama. In the Great Lake region this zone continues westerly across southern Michigan and Wisconsin, and then curves northward over the prairie region of Minnesota, covering the greater parts of North Dakota, Manitoba, and the plains of the Saskatchewan; thence bending abruptly south, it crosses eastern Montana and Wyoming, including parts of western South Dakota and Nebraska, and forms a belt along the eastern base of the Rocky Mountains in Colorado and northern New Mexico, here as elsewhere occupying the interval between the Upper Sonoran and boreal zones.

In Wyoming the transition zone passes broadly over the well-known low divide of the Rocky Mountains, which affords the route of the Union Pacific Railway, and is directly continuous with the same zone in parts of Colorado, Utah, and Idaho, skirting the boreal boundaries of the Great Basin all the way around the plains of the Columbia, sending an arm northward over the dry interior of British Columbia, descending along the eastern base of the Cascade Range and the High Sierra to the southern extremity of the latter, and occupying the summits of the coast ranges in California and of many of the desert ranges of the Great Basin.

The transition zone, as its name indicates, is a zone of overlapping of boreal and Sonoran types. Many boreal genera and species here reach the extreme southern limits of their distribution, and many Sonoran genera and species their northern limits. But a single mammalian genus (*Synaptomys*) is restricted to the transition zone, and future research may show it to inhabit the boreal region also.

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* Prof. Louis Agassiz, in his highly important work on Lake Superior, clearly recognized the transition nature of this zone, for he says: "The State of Massachusetts, with its long arm stretched into the ocean eastward, or rather the region extending westward under the same parallel through the State of New York, forms a natural limit between the vegetation of the warm temperate zone and that of the cold temperate zone. - - - Not only is this also the northern limit of the culture of fruit trees, but this zone is equally remarkable for the great variety of elegant shrubs which occur particularly on its northern borders, where we find so great a variety of species belonging to the genera Celastrus, Cratægus, Ribes, Cornus, Hamamelis, Vaccinium, Kalmia, Rhodora, Azalea, Rhododendron, Andromeda, Clethra, Viburnum, Cephalanthus, Prinos, Dirca, Celtis, etc." (*Lake Superior,* 1850, 182–183.)

The following boreal genera of mammals disappear in the transition zone:

| | | | |
|---|---|---|---|
| Tamias.* | Zapus. | Vulpes.* | Ursus.* |
| Fiber.† | Erethizon. | Cervus. | Neurotrichus. |
| Evotomys. | Arctomys. | Ovis.* | Condylura. |

The following Sonoran genera of mammals disappear in the transition zone:

| | | | |
|---|---|---|---|
| Antilocapra. | Geomys. | Perognathus. | Urocyon.‡ |
| Cynomys. | Thomomys.§ | Bassariscus.‡ | Scalops. |
| Spilogale.‡ | | | |

As already stated, the only mammalian genus apparently restricted to the transition zone is *Synaptomys*, a lemming mouse. A number of species however seem to be nearly or quite confined to this zone. Among these are the following:

Sciurus aberti.
fossor.‖
carolinensis leucotis.
Tamias merriami.
minimus.
pictus.
striatus.
Spermophilus elegans.
richardsoni.
obsoletus.
Arvicola pallidus.
Synaptomys cooperi.
Lepus americanus virginianus.
campestris.
idahoensis.‖
sylvaticus nuttalli.‖

Spermophilus spilosoma pratensis.
grammurus.
townsendi.‖
Cynomys leucurus.
Sitomys nebrascensis.
boylii.
michiganensis.
Arvicola mogollonensis.
austerus minor.
curtatus.
Perognathus fasciatus.
olivaceous.
Putorius nigripes.‖
Vulpes velox.
Scapanus americanus.
Vespertilio melanorhinus.

Local elevations of the land in the Sonoran region are capped with isolated patches of transition or boreal species, according to the temperature to which their summits attain; and if the elevation is sufficient to secure a boreal fauna and flora, the latter is always separated from

* Except one species, which inhabits a limited part of the Sonoran region.

† *Fiber* ranges south beyond the normal limit of the transition zone, but it does so along the banks of cool streams that give it a much lower temperature than that of the surrounding atmosphere. It is probable that both *Fiber* and *Castor* should be classed with aquatic species, the limits of their distribution depending on the temperature of the water. The same is true in a less degree of the paludal sub-genera *Neosorex* and *Atophyrax* (of *Sorex*) and of the semi-amphibious members of the subgenus *Mynomes* (of *Arvicola*).

‡ These genera barely enter the transition zone at all except in a very small area in the far West.

§ Except on high mountains in the Sonoran region.

‖ Range down into Upper Sonoran also.

the Sonoran of the surrounding plane by a belt or girdle of transition zone forms.

The tropical region reaches the United States at two remote points—Florida and Texas. In the former it exists as a narrow sub-tropical belt encircling the southern half of the peninsula from Cape Malabar on the east to Tampa Bay on the west. In Texas it crosses the Lower Rio Grande from Mexico, and extends north to the Nueces River. In western Mexico the tropical region reaches Mazatlan.

Fourteen families of tropical mammals inhabit North America north of Panama, namely:

| | | | |
|---|---|---|---|
| Didelphidæ. | Dicotylidæ. | Procyonidæ. | Hapalidæ. |
| Bradypodidæ. | Tapiridæ. | Solenodontidæ. | Cebidæ. |
| Myrmecophagidæ. | Octodontidæ. | Emballonuridæ. | |
| Dasypodidæ. | Dasyproctidæ. | Phyllostomatidæ. | |

Of the above fourteen families, six reach the United States, namely, *Didelphidæ*, *Dasypodidæ*, *Dicotylidæ*, *Procyonidæ*, *Emballonuridæ*, and *Phyllostomatidæ*, and two of the latter (*Didelphidæ* and *Procyonidæ*) penetrate the entire breadth of the Sonoran region, the *Procyonidæ* even entering the lower edge of the Boreal. Descending from families to genera, it is found that no less than sixty-two tropical genera of non-pelagic mammals inhabit North America north of Panama, of which number nine enter the United States from Mexico, namely, *Didelphis*, *Tatusia*, *Dicotyles*, *Nasua*, *Procyon*, *Felis*, *Molossus*, *Nyctinomus*, and *Otopterus*. Of these, *Didelphis*, *Felis*, and *Procyon* now reach considerably further north than the others, as just pointed out in speaking of the families to which they respectively belong. In explanation of this extended range it is found that these genera inhabited North America in pre-glacial times, and as a consequence have become acclimatized to a wider range of climatic conditions. The semi-tropical belt of Florida is not known to possess any tropical mammals except bats and a large indigenous mouse (*Sitomys macropus*),* but it has not been explored by experienced mammal collectors. Still, its recent origin and complete isolation from other tropical areas would indicate the absence of terrestrial species derived from the south. At the same time it is known to be rich in tropical plants, land shells, insects, and birds, as is shown in another part of the present paper (see *post* pp. 404, 405). It contains nine genera of tropical birds, namely *Zenaida*, *Geotrygon*, *Starnænas*, *Rostrhamus*, *Polyborus*, *Crotophaga*, *Euetheia*, *Callichelidon*, and *Cœreba*.

The following sixty-two genera of mammals belong to the North American tropical region. The nine preceded by the letter *S* enter the southern United States, which they penetrate varying distances. *Nyctinomus* and *Otopterus* inhabit the Lower Sonoran zone in common

* Described by the writer as *Hesperomys macropus* in *N. Am. Fauna*, No. 4, Oct., 1890, p. 53.

with the tropical; *Didelphis* pushes completely through the humid division of the Sonoran region; and *Felis* and *Procyon* enter the lower edge of the boreal.

NORTH AMERICAN TROPICAL GENERA.

| | | | |
|---|---|---|---|
| Chironectes. | Stenoderma. | Noctilio. | Mimon. |
| *S* Didelphis. | Chiroderma. | *S* Molossus. | Hemiderma. |
| Bradypus. | Pygoderma. | *S* Nyctinomus. | Glossophaga. |
| Cholœpus. | Sturnira. | Chilonycteris. | Phyllonycteris. |
| Myrmecophaga. | Brachyphylla. | Mormops. | Monophylla. |
| Tamandua. | *S* Felis. | Centurio. | Leptonycteris. |
| Cycloturas. | *S* Procyon. | Desmodus. | Glossonycteris. |
| *S* Tatusia. | Bassaricyon. | Diphylla. | Chœronycteris. |
| *S* Dicotyles. | *S* Nasua. | Midas. | Artibeus. |
| Elasmognathus. | Cercoleptes. | Mycetes. | Vampyrops. |
| Capromys. | Galictis. | Lonchorhina. | Chrysothrix. |
| Plagiodontia. | Solenodon. | *S* Otopterus, | Nyctipithecus. |
| Echinomys. | Natalus. | Vampyrus. | Ateles. |
| Synetheres. | Rhynchonycteris. | Micronycteris. | Cebus. |
| Dasyprocta. | Saccopteryx. | Trachyops. | |
| Cœlogenys. | Diclidurus. | Phyllostoma. | |

Recapitulating, it is found that of the 134 genera of non-pelagic mammals inhabiting North America north of Panama, 53 are exclusively tropical, 20 exclusively Sonoran, and 20 exclusively boreal. In addition to these genera, which do not outstep the limits of the regions to which they severally belong, a number of others are clearly referable to the same regions, though ranging varying distances beyond their proper boundaries. Including these genera, the number belonging to each region is as follows: Tropical, 62; Sonoran, 34; boreal, 31; thus leaving but 7 genera out of a total of 134 that are not distinctly referable to one of the three regions. One of these (*Synaptomys*) is not known to occur outside the limits of the transition zone, leaving but six genera that have not been assigned. These genera are *Sciuropterus*, *Sciurus*, *Spermophilus*, *Lepus*, *Canis*, and *Lutra*, each of which ranges over large parts of both boreal and Sonoran regions. All except *Spermophilus* inhabit the tropical region also, and all are of great antiquity, as will be shown presently (p. 393). The genera *Spermophilus* and *Lepus* might be referred to the Sonoran region, because the great majority of their species are confined to it; and for the same reason *Sciurus* might be considered tropical and Sonoran.

Omitting Mexico and Central America, and regarding the 9 intrusive tropical genera already mentioned as Sonoran (in contradistinction to boreal), it is found that 81 genera of non-pelagic mammals inhabit the United States and Canada, of which 43 may be looked upon as of Sonoran origin and 31 as of boreal origin. The 7 genera remaining are those mentioned in the last paragraph.

*Geographic distribution of North American genera of nonpelagic mammals occurring north of Mexico.*

BOREAL GENERA.

| | | | |
|---|---|---|---|
| Cervus. | Arctomys. | Cuniculus. | Gulo. |
| Rangifer. | Aplodontia. | Zapus. | Mustela. |
| Alce. | Castor.* | Erethizon. | Lutreola.* |
| Ovis.* | Arvicola.* | Lagomys. | Putorius.* |
| Mazama. | Fiber.* | Vulpes.* | Sorex.* |
| Bison. (?) | Evotomys. | Ursus.* | Neurotrichus. (?) |
| Ovibos. | Phenacomys. | Thalarctos. | Condylura. |
| Tamias.* | Myodes. | Latax. | |

SONORAN GENERA.

| | | | |
|---|---|---|---|
| Cariacus.† | Geomys. | Bassariscus. | Corynorhinus. |
| Antilocapra. | Thomomys. | Taxidea. | Euderma. |
| Cynomys. | Dipodomys. | Conepatus. | Antrozous. |
| Reithrodontomys. | Perodipus. | Mephitis.† | Nycticejus. |
| Onychomys. | Microdipodops. | Spilogale. | Vesperugo.† |
| Sitomys.† | Perognathus. | Motiosorex. | Atalapha.† |
| Oryzomys. | Heteromys. | Blarina.† | Vespertilio.† |
| Sigmodon. | Lynx.† | Scapanus. | |
| Neotoma.† | Urocyon. | Scalops. | |

TROPICAL GENERA.

| | | | |
|---|---|---|---|
| Didelphis. | Felis.† | Nasua. | Nyctinomus. |
| Tatusia. | Procyon.† | Molossus. | Otopterus. |
| Dicotyles. | | | |

TRANSITION ZONE GENERA.

Synaptomys.

GENERA INHABITING BOTH BOREAL AND SONORAN ZONES.

| | | | |
|---|---|---|---|
| Sciuropterus. | Spermophilus. | Lutra. | Lepus. |
| Sciurus. | Canis. | | |

## DISTINCTNESS OF THE TROPICAL REGION FROM THE SONORAN.

It has been shown that the fauna and flora of tropical America reach the United States, though in a somewhat dilute condition, along the Lower Rio Grande in Texas and in southern Florida, and that in the vast majority of cases their genera and species differ widely from those of other parts of America. Except for the presence, chiefly in the southern United States, of a comparatively few forms derived from the tropical region, the fauna and flora of North America are as distinctive and independent of the existence of this area as if separated from it by the broad ocean. Among the eighty-one genera of non-pelagic *Mammalia* inhabiting North America north of Mexico the number of these

* Having one species in Sonoran zone or reaching Sonoran.

† Having one species in Boreal zone or reaching southern edge of Boreal.

intrusive genera is only nine,* as has been shown, and three of these are bats. These genera are: *Didelphis Tatusia, Dicotyles, Felis, Procyon, Nasua, Molossus, Nyctinomus*, and *Otopterus. Tatusia* and *Nasua* barely reach our southern boundary; *Dicotyles* extends only part way through Texas; *Molossus* a short distance into southern California; *Nyctinomus* and *Otopterus* do not pass beyond the lower Sonoran zone, and *Didelphis* is restricted to the humid division of the Sonoran. Out of the nine intrusive genera, therefore, but two (*Felis* and *Procyon*) reach the southern edge of the Boreal.

On the other hand, a few groups, such as the wolves, otters, squirrels, and rabbits (genera *Canis, Lutra, Sciurus, Sciuropterus, Spermophilus*, and *Lepus*) occur over large parts of both North and South America, presenting a seeming obstacle to the acceptance of the view that the faunas in question are so wholly dissimilar. But investigation shows that these animals are almost world-wide in distribution, implying great antiquity of origin, and remains of most of them have been found as low down at least as the Miocene strata in both America and Eurasia. Hence it is clear that these types became diffused over North and South America at a very distant period, and their peculiar habits of life, though wholly dissimilar, enabled them to survive the great mutations these land areas have undergone since Miocene times.

The paucity of species of tropical derivation in North America is the more remarkable in view of the absence of barriers of any kind, save climatic conditions alone, to impede the free ingress of species from the south. No mountain range or arm of the sea or other tangible obstacle marks the northern boundary of the semi-tropical fauna of northeastern Mexico, where it ends abruptly near the Nueces River in Texas, or the semi-tropical belt of Florida, where it ends near Tampa Bay on the west and Cape Malabar on the east.

If the tropical fauna and flora stopped at the narrow Isthmus of Panama, or even in southern Nicaragua, where the last union of the North and South American continents probably took place, the case would be very different, but instead of doing this it pushes northward 1,500 to 2,000 miles and ends abruptly where the most painstaking search fails to reveal any barrier to further extension, except an uncongenial decrease in temperature and humidity. (See also remarks under change of climate following Pleistocene times, p. 398.)

No more striking illustration could be desired of the potency of climate compared with the inefficiency of physical barriers than is presented by the almost total dissimilarity of the North American Tropical and Sonoran regions, though in direct contact, contrasted with the great similarity of the Boreal regions of North America and Eurasia, now separated by broad oceans, though formerly united doubtless in the region of Bering Sea. Of the thirty-one Boreal genera of North

* Among birds the number of intrusive forms is greater, as would be expected from their superior powers of locomotion and dispersion.

American mammals all but eight, or three-fourths, occur also in Eurasia, and but a single family is restricted to cold-temperate America. This family (the *Aplodontidæ*) is the sole representative of a group approaching extinction, and the accident of its survival (in a single genus and two closely related species) in a very limited area along our west coast can hardly be construed as of much faunal significance. Contrasted with this one family (which ought not to be counted) and eight genera of Boreal North American mammals not occurring in Eurasia, tropical North America (Central America and part of Mexico, exclusive of the West Indies) has no less than eight families and fifty-three genera not belonging to the immediately adjoining Sonoran region of the southern United States and the plateau of Mexico.

### THE SONORAN NOT A TRANSITION REGION.

Before leaving this part of the subject reference should be made to the view recently advanced by some naturalists, notably by Angelo Heilprin, that the Sonoran region is itself a "Transition region" between the Boreal and Tropical faunas and floras. The incorrectness of this hypothesis is easily demonstrated, for it rests upon the assumption that the Sonoran region is a mixture of Boreal and Tropical forms. The contrary has just been shown to be the case, the hiatus between the Sonoran and Boreal on the one hand and the Sonoran and Tropical on the other being not only immense, but vastly greater than that between Boreal America and Eurasia.

### DIFFERENTIATION OF LIFE FROM THE NORTH SOUTHWARD.

Animals and plants inhabiting the Arctic regions are usually specifically identical throughout Arctic America, Greenland, and the polar parts of Eurasia and outlying islands, while as they diverge from the pole southward they tend to split up into many species; in other words, Boreal species are more stable and persistent than those inhabiting warmer countries. The explanation of this fact is obvious. The identity of climate and environment throughout the Arctic zone tends to preserve identity of specific characters, giving rise to a homogeneous fauna and flora, while the diversity of physical conditions and climatic influences prevailing in an increasing degree at greater distances from the pole exerts a powerful influence upon the various forms of life, producing first local geographic races or sub-species, then species, and finally groups of species constituting well-marked sub-genera and even genera, giving rise to greatly diversified faunas and floras. Thus among mammals the polar or ice bear (*Thalarctos maritimus*) has no very near relative, and is replaced in the tundras by the brown and barren-ground bears (*Ursus arctos* and *richardsoni*), which run into several more or less distinct forms, as the snow bear (*U. isabellinus*), Syrian bear (*U. syriacus*), and hairy-eared bear (*U. piscator*). Besides

these are the grizzly (*U. horribilis*), of which two forms may be recognized) and the black bears of America and Eurasia (*U. americanus*, *torquatus*, and *japonicus*); and still farther southward the group becomes differentiated into several well-marked genera.

In like manner the Arctic fox is replaced to the southward, first, by the red foxes of America and Eurasia, of which several sub-species are known; second, by a number of quite distinct species; and third, by additional types, at least one of which in our country is entitled to generic rank (*Urocyon*).

The ermine and polar hare are the sole Arctic representatives of groups which in the temperate parts of Europe and America comprise many distinct species, and in the case of the former, several well-marked sub-genera.

The Arctic lemmings (genera *Myodes* and *Cuniculus*) are numerously represented in the north temperate parts of the world by the genera *Ellobius*, *Synaptomys*, *Phenacomys*, *Evotomys*, *Fiber*, and *Arvicola*.

It is not to be inferred from the above remarks that the polar representatives of these various groups are to be looked upon as the parent stocks from which the other members sprang. Usually the reverse is the case, for groups of Boreal origin that now attain their maximum development in the north temperate regions have their number reduced in the Arctic circle to a single representative. But regardless of centers of origin, it is here intended to emphasize the fact that types inhabiting the Arctic zone are few in number and uniform in character throughout their distribution, while to the southward the same types become more and more diversified and new types appear as the distance from the pole increases,* so that it may be formulated as a general proposition that in continental areas *the further from the poles, the larger the number of families, genera, and species.* †

* The elder Agassiz long since pointed out that "the vegetation of the two continents becomes more and more homogeneous the more we advance northward." (Lake Superior, 1850, 153.) Stated conversely, this is in complete accord with the "Law of differentiation from the north southward" formulated by Allen as "a constant and accelerated divergence in the characters of the animals and plants of successive regions of the continent." (*Bull. Mus. Comp. Zoöl.* II., 1871, 379.) In a later contribution the same author speaks of the "high rate of differentiation favored by tropical conditions of climate," and adds that Arctic and cold-temperate climates are characterized by only slightly or moderately diversified faunas; that a moderate increase of temperature results in the addition of many new types; and that "a high increase in temperature, giving tropical conditions of climate," is accompanied by "a rapid multiplication of new forms and a maximum of differentiation."

† This is a general proposition intended to apply to terrestrial forms of life *collectively*, and does not conflict with the law that the maximum number of species in each particular group is found in the zone or area which is the center of its distribution.

### ORIGIN OF TYPES AND FAUNAS—GEOLOGIC EVIDENCE.

In speaking of the Boreal and Sonoran origin of species and groups in the present paper, the term "origin" is used exclusively in a sense intended to indicate present centers of distribution—not real or ancient centers of origin; for it must be borne in mind that the history of the inhabitants of the earth is not only a history of the successive appearance and disappearance of types now extinct, but a history of great movements—of vast migrations to and fro over the surface of the globe, and little is known of the real points of origin of our Boreal and Tropical faunas and floras. The geologic evidence demonstrates that in the past large land areas have been many times joined together and many times rent asunder. The establishment of land continuity between areas previously disconnected has made it possible for new forms of animals and plants to obtain a footing and spread over regions previously uninhabited by them,—often doubtless at the expense of the indigenous fauna and flora. Even great continents, as North and South America, have been more than once united and separated; and the last union of these continents is so recent we can distinctly trace at the present day the course and distribution of the intrusive forms.

On the other hand, in comparatively recent times, multitudes of species and genera, and even families and higher groups, have suddenly disappeared from large areas where they were formerly abundant, and some of them from the face of the earth, so that the fauna of the recent past compared with that of to-day presents some strange contrasts. North America in Pleistocene times was inhabited by associations of mammals not now living on this continent, but found in as far distant parts of the earth as Asia and South America; for horses, camels, and elephants then lived here with llamas, tapirs, and capybaras. With them were others now altogether extinct, as huge tigers, wolves, cave bears, the great Mastodon, the Megatherium, Megalonyx, Mylodon, and other gigantic sloths.

### GLACIAL EPOCH.

The cause of this sudden extermination of dominant types is believed to have been the Glacial epoch, which is known to have driven species of animals and plants from the poles to the tropics, and which explains several of the otherwise inexplicable problems presented in the study of the past and present distribution of life.

The snows at the beginning of the Glacial epoch fell upon a continent of great forests—forests that gave shelter to multitudes of mammals and birds and other forms of life, a large proportion of which no longer inhabit America, and many of which do not exist in any part of the globe.

During the period of maximum development the great glacier is believed to have been not less than 8,000 feet in thickness in northern

New England, and its southern border crossed New Jersey and Pennsylvania, and thence, curving irregularly southwesterly to southern Illinois and then northwesterly, finally reached the Pacific Ocean in British Columbia. The disastrous effect upon animals and plants of this tremendous body of ice must have reached far south of its actual borders.

The Glacial epoch is believed to have been made up of at least two principal and a number of minor advances and retreats, separated by long intervals and accompanied doubtless by corresponding fluctuations in the northern boundaries of the faunal and floral areas immediately to the south; for it is reasonable to suppose that throughout the period covered by the movements of the ice mantle, and probably in later pre-glacial times as well, the forms now known as Boreal and Arctic (or their immediate ancestors) inhabited areas characterized by temperatures not very different from those they now require, and that the northern limit of each species kept at a certain uniform distance from the ice line. "Plants," says Dr. Gray, "are the thermometers of the ages, by which climatic extremes and climates in general are best measured."

Important evidence of the correctness of this hypothesis is afforded by the well known presence of colonies or assemblages of arctic species on isolated mountain summits in southern latitudes, where the altitude carries them into the low temperature of their homes in the far north. It is obvious that such colonies could not have reached their present positions during existing climatic conditions. But during the return movement of animal and plant life following the retreat of cold at the close of the Glacial epoch, many Boreal species were stranded on mountains, where, by climbing upward as the temperature increased, they were enabled to survive, finding a final resting place with a climate sufficiently cool for their needs, and here they have existed to the present day.*

Throughout the growth of the great ice mass and its extension from the north southward it is clear that the animals and plants that could not keep pace with its advance must have perished, while the steady pushing toward the tropics of those that were able to escape to the rapidly narrowing land in that direction must have resulted in an overcrowding of the space available for their needs and a corresponding increase in the severity of the struggle for existence. The sustaining capacity of a region is limited; hence such a thing as over-crowding, in the sense of greatly increasing the number of organisms a region can support, is an impossibility, for beyond a certain limit all excess of life

* In a former communication attention was called to the circumstance that the presence or absence of such arctic-alpine colonies on high volcanic mountains may be of use to the geologist as affording evidence of the age of the volcanic activity resulting in the upheaval of the mountain, the absence of Arctic or Boreal forms indicating postglacial origin. (*N. Am. Fauna*, No. 3, September, 1890, p. 21.)

must perish,—over-crowding inevitably leading to death. The mortality in any one year may not have been great, but during the many thousands of years covered by the movements of the continental ice the aggregate destruction of life must have been stupendous.

Immediately upon the close of the Glacial epoch, life began to reclaim the regions from which it had been so long shut out. This overflow released the tension under which the animals and plants had been struggling for ages and rendered the contest for existence less severe. Over-production had at last found an outlet, and life became possible to a constantly increasing number of individuals. Normal reproduction was sufficiently rapid to supply occupants for the regions made habitable by the slow recession of the ice, and the advance of both plants and animals kept pace, doubtless, with its progressive increase. But the species that survived to return were only in part those driven out. Many had been overtaken by the cold or had perished in the journey southward; others were driven into inhospitable regions where the environment was not suited to their needs; others still succumbed in the struggle resulting from over-crowding, and some that outlived the first great period of glaciation perished during the second. Gilbert tells us that a detailed study of the ancient lake beds of the Great Basin "shows two lacustral epochs corresponding to two glacial epochs, and correlates the mammalian fauna with the later half of the later Glacial epoch. Presumptively this date falls very late in the Pleistocene period." ("Lake Bonneville," by G. K. Gilbert, 1890, 397.) The mammalian fauna referred to comprises an elephant, an otter, two horses, three llamas, a deer of the genus *Cervus*, an ox, a gigantic sloth, together with three species now living, namely, the coyote, beaver, and pocket gopher (*Thomomys*). No new types came in to take the place of those exterminated; hence we in the United States now live in a region deprived of many of the groups to which it gave birth, and we are forced to visit remote parts of the earth to see animals and plants that once attained their maximum development in North America, while others that formerly flourished here are entirely extinct.

Not only are the pre-Pleistocene animals and plants now represented imperfectly and in greatly reduced numbers, but the areas at present inhabited by their descendants, except in the case of the Boreal forms, are insignificant in comparison with their former extent. It should be remembered that the refrigeration of the Glacial epoch has only in part disappeared. In early Pliocene times characteristic representatives of sub-tropical faunas and floras existed northward over much of the United States and Canada, and in still earlier times reached the Arctic Circle.* During the advance of cold in the Glacial epoch these forms were either exterminated or driven southward into the narrow tropical parts of Mexico and Central America. The retreat of cold at the ter-

*Among trees fossil remains of magnolia, sassafras, and liquidamber have been found in Greenland.

mination of this period was not complete, and our continent has never regained its former warmth. Hence the expelled species were not permitted to advance more than a short distance into the region formerly occupied by them, and the tropical species have been held back and at the present day are not found except along the extreme southern confines of our territory. For example, peccaries in early Pleistocene times ranged northward over a large part of western America, while at present they are restricted to parts of Texas and Louisiana below the Red River of the South; and the capybaras, tapirs, and other tropical forms whose fossil remains have been found in many parts of the United States have not been able to return. The same is true of plants; for the palms, tree ferns, and numerous other tropical types that formerly ranged over much of our country, are now either altogether extinct or exist only in the tropics.

The llama—and many plants—now inhabiting the Andes may be looked upon as representing a class of cases in which Boreal forms were driven so far south that they actually reached the great mountain system of South America, and spread southward over its elevated plateaus and declivities to the extreme end of the continent in Patagonia and Terra del Fuego. This fact has been long recognized by botanists.

The palæontologic history of the earth shows that many groups now unknown came into existence from preceding groups, gradually attained a maximum development, and as gradually passed away; but there are few records of breaks in the geologic series, or of disturbances of any kind from the earliest appearance of life to the present time, that have resulted in the destruction of so many types as the cold of the Glacial epoch.

### CAUSES CONTROLLING DISTRIBUTION.

It is now pretty generally conceded that temperature and humidity are the chief factors governing the distribution of life, and that temperature is more potent than humidity. Illustrations of this law have been already given in contrasting the humid and arid elements of the several zones with the zone elements as limited by temperature, and it has been found in the case of mammals and birds that the effects of temperature, estimated numerically, are more than three times greater than the effects of humidity upon genera, and many times greater upon the higher groups.

Authors differ as to the exact period during which temperature exerts the greatest influence, but there can be little doubt that for both animals and plants it is the season of reproductive activity, and hence varies inversely with latitude and altitude. In high arctic latitudes this period is very brief, while in the humid tropics it seems to extend over nearly if not quite the whole year.*

* This was pointed out by the author in *North Am. Fauna*, No. 3, September, 1890, pp. 26, 27.

Whether the temperature in question is the mean of a certain period or the sum of the daily temperatures for that period, or the sum in excess of a certain minimum, expressed in degrees of the thermometric scale or in calories, and how to determine the precise beginning and ending of this period for each locality, are questions respecting which difference of opinion prevails; and authors are not agreed as to whether the temperature should be taken in the sunshine or in the shade, or at a certain distance below the surface of the earth. At the same time it has been demonstrated by Linsser and others that a definite quantity of heat is required to complete the process of reproduction in a number of plants experimented upon,—and nature's laws are not framed for isolated cases. This law is taken advantage of by expert gardeners and horticulturists who are able to so regulate the temperature of their greenhouses that they can produce a perfect flower or a ripe fruit on a specified day.

A few species (particularly among plants) are so sensitive to cold that they are limited in northward range by the line of killing frost but in the vast majority of cases the winter temperature is of no consequence. As I have already shown, "The season of reproduction for the plant, as for the animal, is the warm part of the year. After the period of reproduction the plant withers; after it flowers and fruits and matures its seed, it dies down or becomes physiologically inactive. And what the plant accomplishes in one way the animal accomplishes in another. To escape the cold of winter and its consequences, the sensitive mammal hibernates; the bird migrates to a more southern latitude; the reptile and batrachian dig holes in the mud or sand and remain in a torpid condition; the insect sleeps in its cocoon or buries itself under leaves or decomposing vegetation; and none but the hardier forms of life are left to be affected by winter temperatures." (*N. Am. Fauna*, No. 3, September, 1890, 26, 27.)

After temperature and humidity, several subordinate though important factors remain to be considered. Among these may be mentioned the duration and actinic effects of sunlight (governed in part by percentage of cloudiness or fog and by the mechanical purity of the atmosphere). The character of the soil also determines the presence or absence of many species.*

## EFFECTS OF HUMIDITY CONTRASTED WITH EFFECTS OF TEMPERATURE.

With a few exceptions the Boreal zones, owing to their low temperatures, precipitate sufficient moisture to support arboreal vegetation, and do not possess arid areas. The Transition and Sonoran zones, on the other hand, naturally fall into two important subdivisions, arid and

*The controlling causes of distribution will not be discussed further here because they are the subject of another communication upon which the writer is engaged.

humid, as indicated in defining their courses. As a rule, the former consist of treeless plains, deserts, and barren mountains, while the latter are bountifully clothed with forests. Most of the humbler forms of vegetation are different in the two sub-divisions, and differences exist also among the mammals, birds, and reptiles, but the great majority of these dissimilarities are not of the same kind as those that distinguish one zone from another. Most of them are specific, not generic, and the number of distinctive groups of high order is very much less. This may be made clear by selecting the distinctive elements of the arid Sonoran (which has the largest number of peculiar forms) in comparison with those of the humid Sonoran (or Austro-riparian) and contrasting them numerically with the distinctive elements of the Sonoran as a whole compared with those of the Boreal as a whole.* Among non-pelagic mammals the arid Sonoran has one family (*Antilocapridæ*) and only ten genera† not known to inhabit the humid Sonoran or Austro-riparian, and the latter has but one family (*Didelphidæ*) and four genera *Didelphis*, *Oryzomys*, *Scalops*, and *Nycticejus*) not found in the arid Sonoran (and the family and one of the genera are intrusions from the Tropical region), while thirteen families and twenty-seven genera are common to both arid and humid subdivisions.‡

Among birds the arid Sonoran has no family and only twenty-four genera not inhabiting the humid Sonoran, and the latter has no family and but seven genera not found in the arid, while twelve families and thirty-one genera are common to the two divisions.

Contrasting the Sonoran as a whole with the Boreal as a whole, it appears that there are no less than eight families and forty-one genera of mammals and ten families and about one hundred genera of birds distinctive of the Sonoran, and six families and thirty genera of mammals and three families and about forty genera of birds distinctive of the Boreal zone. In other words, taking mammals and birds together, the arid Sonoran has one peculiar family and only thirty-four distinctive genera, and the humid Sonoran one family and eleven genera (of which the family (*Didelphidæ*) and several of the genera are clearly intrusions from the tropical region), while the Sonoran as contrasted with the Boreal has eighteen distinctive families and one hundred and forty-one distinctive genera, and the Boreal has nine distinctive families and seventy distinctive genera.

Only eight families and eight genera of mammals are common to the Boreal and Sonoran regions. The common families are: *Cervidæ*, *Muridæ*, *Sciuridæ*, *Leporidæ*, *Mustelidæ*, *Canidæ*, *Felidæ*, and *Soricidæ*.

*The intrusive tropical genera are here treated as Sonoran.

†These genera are: *Antilocapra*, *Cynomys*, *Onychomys*, *Thomomys*, *Dipodomys*, *Perodipus*, *Microdipodops*, *Perognathus*, *Bassariscus*, and *Antrozous*.

‡The newly discovered genus of *Chiroptera*, *Euderma*, is here omitted because only a single specimen is known, and it can not yet be satisfactorily assigned to its proper faunal position.

The common genera are: *Sitomys*, *Sciurus*, *Sciuropterus*, *Spermophilus*, *Lepus*, *Lutra*, *Canis*, and *Lynx*. Several others inhabit limited parts of both regions, but are not common to these regions as a whole.

With the possible exception of the gray wolf, not a single species of mammal ranges throughout the Sonoran and Boreal zones, though a number are common to the Upper Sonoran and Lower Boreal (Canadian); and in the case of the wolf it is almost certain that comparison of specimens will show the animal of the southern United States and Mexico to be perfectly distinct from that of Arctic America. The ermine is another species of exceptional though less extensive range, if it is really true that the weasel inhabiting the shores and islands of the Polar Sea is specifically identical with that found in the more elevated parts of the Southern States,—an assumption I can not for a moment entertain.

In the case of land birds, eighteen genera are common to the Boreal and Sonoran regions. The number of common families is relatively large as would be expected from the wide dispersal of most families of birds. For instance, the *Turdidæ* or thrushes inhabit North and South America, Eurasia, Africa, India, and Australia; the *Paridæ* or titmice inhabit North and South America, Eurasia, Africa, India, Australia, and New Zealand; the *Cinclidæ* or dippers inhabit North and South America, Eurasia, India, and the Austro-Malayan region; the *Troglodytidæ* or wrens inhabit North and South America, Eurasia, India, Africa, and the Austro-Malayan region; the *Corvidæ* or crows, magpies and jays, are found in every part of the world, and so on.

*Number of distinctive families and genera of Mammals and Birds of the arid Sonoran compared with the humid Sonoran, and of the Sonoran as a whole compared with the Boreal as a whole.*

| | Mammals. | | Birds. | | Total. | |
|---|---|---|---|---|---|---|
| | Family. | Genera. | Family. | Genera. | Family. | Genera. |
| Arid Sonoran distinguished from humid Sonoran by | 1 | 10 | 0 | 24 | 1 | 34 |
| Humid Sonoran distinguished from arid Sonoran by | 1 | 4 | 0 | 7 | 1 | 11 |
| Common to both arid and humid sonoran | 13 | 27 | 12 | 31 | 25 | 58 |
| Sonoran as a whole distinguished from Boreal by | 8 | *41 | 10 | 100 | 18 | 141 |
| Boreal as a whole distinguished from Sonoran by | 6 | †30 | 3 | 40 | 9 | 70 |
| Common to Boreal and Sonoran | 8 | 8 | .......... | 18 | .......... | 26 |

* *Sitomys* and *Lynx* are omitted because they range over most of the forested part of the Boreal region.

† *Putorius* is omitted because it ranges over much of the Sonoran region.

Descending to the species the contrast is even more marked.

The above table shows, so far as the genera of mammals and birds are concerned, that the difference between the humid "Atlantic" or "Eastern province" on the one hand, and the arid Great Plains and Great Basin on the other, is less than one-fourth as great as the difference between the Sonoran and Boreal regions.

These facts, it seems to me, should suffice to establish beyond dispute the subordinate part played by humidity in comparison to temperature, and should dispel any lingering doubts that may still haunt the minds of conservative naturalists respecting the necessity of abandoning the long accepted division of the United States into Atlantic, Central, and Pacific provinces.

### REMARKS CONCERNING SOME OF WALLACE'S STATEMENTS.

Wallace, in his great work on geographic distribution, and in subsequent writings on the same subject, greatly under-rates the importance of temperature as a factor in determining the distribution of life. He lays great stress upon the dissimilarity of the faunas and floras of parts of Africa, South America, and Australia lying in the same latitude, and calls particular attention to the circumstance that although the climate may be identical over these widely separated areas, the species and higher groups are totally distinct, because the regions have been disconnected since early geologic times,—as if these facts were not self-evident. On the other hand, in single continental areas where there is no break or barrier of any kind between widely different faunal zones, he tries to invent some unnatural reason for the differences observed, and is reluctant to admit that even in these cases climate or climatic conditions can constitute the barriers to dispersion that undoubtedly exist. He says of climate: "Probably its action is indirect, and is determined by its influence on vegetation, and by bringing diverse groups into competition."

In another place he states: "Hot countries usually differ widely from cold ones in all their organic forms; but the difference is by no means constant, nor does it bear any proportion to difference of temperature. Between frigid Canada and sub-tropical Florida there are less marked differences in the animal productions than between Florida and Cuba or Yucatan, so much more alike in climate and so much nearer together." He states further: "The eastern United States possess very peculiar and interesting plants and animals, the vegetation becoming more luxuriant as we go south, but not altering in essential character; so that when we reach the southern extremity of Florida we still find ourselves in the midst of oaks, sumacs, magnolias, vines, and other characteristic forms of the temperate flora; while the birds, insects, and land-shells are almost identical with those found farther north. But if we now cross over the narrow strait, about 50 miles wide, which separates Florida from the Bahama Islands, we find ourselves in a totally dif-

ferent country, surrounded by a vegetation which is essentially tropical and generally identical with that of Cuba. The change is most striking, because there is no difference of climate, of soil, or apparently of position, to account for it." (*Island Life*, 1880, p. 5.)

Let us examine this statement with some care to see if the facts warrant the assertions and conclusions of the author. But first let me protest against Wallace's habit of contrasting insular faunas with those of continuous land area, in his efforts to minimize the effects of climate. In most cases the great majority of forms peculiar to an island have no means of reaching the nearest continuous land, but in the present instance, as will be shown later, the proximity of Cuba and the Bahamas to Florida, favored by the direction of the Gulf Stream and the prevalence of hurricanes blowing from the Antilles to the peninsula, have enabled a multitude of West Indian plants, insects, birds, and even land shells to reach southern Florida, though the breadth of the strait is an effective bar to the passage of terrestrial mammals and reptiles.

Wallace boldly tells us, without attempt at qualification, that "between frigid Canada and sub-tropical Florida there are less marked differences in the animal productions than between Florida and Cuba." Frigid Canada, in eastern North America, is the home of the Eskimo, polar bear, musk oxen, reindeer, lemmings, marmots, beavers, musk-rats, porcupines, wolverines, sables, shrews, star-nosed moles, and several other mammals, comprising in all twenty genera, not one of which occurs in southern Florida.* Florida, on the other hand, is inhabited by opossums, harvest-mice, rice-field mice, cotton rats, wood rats, pocket gophers, gray foxes, spotted skunks, big-eared bats, and other forms, representing thirteen genera and five families of mammals that do not occur in frigid Canada.† In the case of birds, eastern Canada has twenty-six genera that do not reach Florida, among which may be mentioned ptarmigans, grouse, rough-legged hawks, golden eagles, great gray owls, snowy owls, Acadian owls, hawk owls, three-toed woodpeckers, Canada jays, pine bullfinches, cross-bills, linnets, snow buntings, titlarks, winter wrens, kinglets, and stone chats,‡ while Florida has at

* The following twenty genera of mammals inhabit eastern Canada, but none of them reach southern Florida: *Rangifer, Alce, Ovibos, Tamias, Spermophilus, Arctomys, Castor, Fiber, Arvicola, Erotomys, Phenacomys, Myodes, Cuniculus, Zapus, Erethizon, Thalarctos, Gulo, Mustela, Condylura, Scapanus, Sorex.*

† The following thirteen genera of mammals inhabit Florida, but none of them reach "frigid Canada:" *Didelphis, Reithrodontomys, Oryzomys, Sigmodon, Neotoma, Geomys, Urocyon, Procyon, Spilogale, Corynorhinus, Nycticejus, Nyctinomus, Otopterus.* The five families are: *Didelphidæ, Geomyidæ, Procyonidæ, Emballonuridæ, Phyllostomatidæ.*

‡ The following twenty-six genera of birds breed in eastern Canada, but none of them in Florida: *Dendragapus, Bonasa, Lagopus, Archibuteo, Aquila, Scotiaptex, Nyctala, Nyctea, Surnia, Picoides, Sphyrapicus, Perisoreus, Dolichonyx, Pinicola, Loxia, Acanthis, Plectrophenax, Calcarius, Zonotrichia, Junco, Passerella, Anthus, Anorthura, Certhia, Regulus, Saxicola.*

least thirty-seven genera that do not reach Canada, among which are quails, turkeys, doves of several genera, vultures, caracaras, kites, barn and burrowing owls, parrots, anis, ivory-billed woodpeckers, chuck-wills-widows, cardinals, blue grosbeaks, yellow-breasted chats, mocking birds, and others.*

Thirty out of the above thirty-seven genera breed also in the West Indies.

No less than nine tropical American genera of birds inhabit the sub-tropical belt of Florida, namely, *Zenaida*, *Geotrygon*, *Starnœnas*, *Rostrhamus*, *Polyborus*, *Crotophaga*, *Euetheia*, *Callichelidon*, and *Cœreba*. The following Antillean species and sub-species occur in the same area and are not known from any point farther north: *Colinus virginianus cubanensis*, *Columba leucocephala*, *Zenaida zenaida*, *Geotrygon martinica*, *Starnœnas cyanocephala*, *Rostrhamus sociabilis*, *Falco dominicensis*, *Speotyto cunicularia floridana*, *Polyborus cheriway*, *Crotophaga ani*, *Coccyzus minor maynardi*, *Agelaius phœniceus bryanti*, *Euetheia bicolor*, *Euetheia canora*, *Progne cryptoleuca*, *Petrochelidon flava*, *Callichelidon cyanoviridis*, *Vireo altiloquus barbatulus*, *Cœreba bahamensis*. In addition to these species, the following are restricted, so far as known, to southern Florida: *Meleagris galloparo osceola*, *Chordeiles virginianus chapmani*, *Cyanocitta cristata florincola*, *Ammodramus nigrescens*, *Vireo noveboracensis maynardi*, *Geothlypis trichas ignota*, *Thryothorus ludovicianus miamensis*, *Cistothorus marianæ*, *Sitta carolinensis atkinsi*.

That there are corresponding differences among insects is evident from an important paper by Mr. E. A. Schwarz on the Insect Fauna of semi-tropical Florida. Mr. Schwarz states: "I have come to the conclusion that it (the semi-tropical fauna of Florida) is entirely of West Indian origin, and that the region I shall hereafter circumscribe as semi-tropical Florida does not contain any endemic forms. In other words, the distinctive fauna of southern Florida is a permanent colony of West Indian forms, much more numerous in species than it has hitherto been supposed, the number in *Coleoptera* alone amounting, according to a very low estimate based upon my collection, to at least three hundred species not yet in our catalogues." (*Entomologica Americana*, IV, No. 9, 1888.) Since the above was published, Mr. Schwarz has had the kindness to inform me that this semi-tropical insect fauna of southern Florida comprises in all not less than one thousand species of West Indian or Antillean insects (of which about

* The following thirty-seven genera of birds breed in Florida, but none of them range north to "frigid Canada," though thirty out of the thirty-seven are known to breed in the West Indies: *Colinus*, *Meleagris*, *Columba*, *Zenaidura*, *Zenaida*, *Columbigallina*, *Geotrygon*, *Starnœnas*, *Cathartes*, *Catharista*, *Elanoides*, *Elanus*, *Ictinia*, *Rostrhamus*, *Polyborus*, *Strix*, *Speotyto*, *Conurus*, *Crotophaga*, *Campephilus*, *Antrostomus*, *Aphelocoma*, *Icterus*, *Peucæa*, *Pipilo*, *Cardinalis*, *Guiraca*, *Euetheia*, *Certhiola*, *Protonotaria*, *Helinaia*, *Helmitherus*, *Icteria*, *Mimus*, *Harporhynchus*, *Thryothorus*, *Polioptila*.

half are *Coleoptera*), and fifty genera of *Coleoptera* and *Heteroptera* alone;* hence the total number of genera must be very considerable.

Among the Mollusca, Dr. William H. Dall informs me that twenty species or specific types of Antillean land shells are known to inhabit southern Florida, representing thirteen genera or sub-genera not found farther north.†

So far as vegetation is concerned the case is even stronger, there being upward of three hundred and fifty genera of plants in Florida that do not inhabit Canada; and Prof. Charles S. Sargent, in speaking of the trees of southern Florida, states: "A group of arborescent species of West Indian origin occupies the narrow strip of coast and islands of southern Florida. - - - This semitropical forest belt reaches Cape Malabar on the east coast and the shores of Tampa Bay on the west coast. - - - The species of which it is composed here reach the extreme northern limit of their distribution; they are generally small, stunted, and of comparatively little value. Certain species however attain respectable proportions: the mahogany, the mastic, the royal palm, the mangrove, the sea grape, the Jamaica dog-wood, the manchineel, and other species here become considerable and important trees." (*Forests of North America*, Tenth Census, 1884, p. 6.)

From what has been said, it appears not only that Wallace's statement that "between frigid Canada and sub-tropical Florida there are less marked differences in the animal productions than between Florida and Cuba" is wholly incorrect, but that there exists in Florida a well-marked sub-tropical fauna and flora consisting in the main (except in the case of terrestrial mammals and reptiles which could not reach it) of genera, and largely of species, identical with those of Cuba. This being the case, is it not fair to turn the tables and ask Wallace what constitutes the barrier that so effectually holds back hundreds of genera and a multitude of species of Antillean or tropical American plants, insects, land mollusks, and birds now inhabiting sub-tropical Florida?

* Mr. Schwarz has kindly given me the following list of families of Central American Coleoptera, indicating the number of genera in each family known to inhabit semitropical Florida, but not found elsewhere in North America: *Carabidæ*, 2 genera; *Phalacridæ*, 1; *Coccinellidæ*, 1; *Cucujidæ*, 1; *Mycetophagidæ* 1; *Elateridæ*, 1; *Scarabæidæ*, 2; *Cerambycidæ*, 5; *Chrysomelidæ*, 4; *Tenebrionidæ*, 3; *Monommidæ*, 1; *Otiorhynchidæ*, 1; *Curculionidæ*, 6; *Brenthidæ*, 1 [this is the only genus which reappears at Cape San Lucas]; *Calandridæ*, 3; *Scolytidæ*, 3; *Anthribidæ*, 2. He informs me also that 11 genera of tropical American Heteroptera have been found in the same belt.

† The forms here referred to are: *Strobila hubbardii* Brown; *Helix cæca Helix varians* Mke.; *Bulimulus multilineatus* Say; *Bulimulus dormani* W. G. B.; *Orthalicus undatus* Brug; *Liguus fasciatus* Müller; *Liguus fasciatus* var. *Stenogyra gracillima* Pfr.; *Stenogyra subula* Pfr.; *Macroceramus gossei* Pfr.; *Macroceramus pontificus* Gld. (also occurs in Texas); *Strophia incana* Binn.; *Auricula pellucens* Mke.; *Tralia minuscula* Dall; *Melampus (Detracia) bulloides* Mont.; *Pedipes mirabilis* Mhlf.; *Pedipes elongatus* Dall; *Planorbis tumidus* Pfr.; *Sphærium cubense* Morelet.

The deep arm of ocean between Florida and Cuba or the Bahamas has proved ineffectual in checking their dispersions. What is the more potent barrier that prevents their northward spread along the continuous land of the peninsula? The answer is summed up in the single word climate. The temperature of the period of growth and reproduction in the northern parts of Cuba and the Bahamas is the same as in sub-tropical Florida, but to the northward it falls off rapidly.

Respecting Wallace's statement that the difference between the faunas and floras of hot and cold countries "is by no means constant," and does not bear "any proportion to difference of temperature," it need only be said that no phenomenon of nature is more constant; and that the differences observed depend directly upon temperature. President D. S. Jordan has said: "In many groups, anatomical characters are not more profound or of longer standing than are the adaptations to heat and cold." (*Popular Science Monthly*, Aug., 1890, XXXVII, p. 506.)

That "life is distributed in circum-polar zones, which conform with the climatic zones, though not always with the parallels of the geographer" is a law recognized by Humboldt, Wagner, Agassiz, Dana, De Candolle, Allen, and nearly all writers on distribution except Wallace. This law does not imply that the same species, genera, or higher groups recur under the same degree of heat in disconnected land areas—a manifest impossibility,—but that well-marked zones of animal and plant life are encountered in all parts of the earth in passing from the poles to the tropics; that they owe their existence to constant differences of temperature, and that in continuous land areas each zone may be traced completely across such areas (from ocean to ocean in those of continental magnitude), following the windings of the belts of equal temperature during the period of reproductive activity.

Wallace speaks thus of this law as formulated by Allen: "The author (J. A. Allen) continually refers to the 'law of the distribution of life in circum-polar zones,' as if it were one generally accepted and that admits of no dispute. But this supposed 'law' only applies to the smallest detail of distribution—to the range and increasing or decreasing numbers of species as we pass from north to south, or the reverse; while it has little bearing on the great features of zoölogical geography—the limitations of groups of genera and families to certain areas." (*Geog. Dist. of Animals*, 1876, vol. I, p. 67.) Mr. Allen has already pointed out the weakness of this criticism (*Bull. U. S. Geol. and Geog. Survey Terr.*, May, 1878, vol. IV, No. 2, 326), and I would like to add a word respecting the extraordinary statement that circum-polar distribution affects species only, having "little bearing" on the "limitations of groups of genera and families." In refutation of this fallacy it is hardly necessary to do more than call attention to the circumstance that the trans-continental Sonoran region of North America is distinguished from the Boreal by the possession of seven families and thirty-

four genera of mammals alone,* and the North American Tropical from the Sonoran by ten families and upwards of fifty genera; while the American Boreal differs from the Eurasian Boreal by the possession of but a single family and only eight genera.

### MOUNTAINS AS BARRIERS TO DISPERSION.

Wallace makes the surprising statement that on the two sides of the Rocky mountains in America "almost all the mammalia, birds, and insects are of distinct species,"†—a statement that is wholly untrue, as has been long known to American naturalists. In another place he makes the general statement that mountains, "when rising to a great height in unbroken ranges, form an impassable barrier to many groups." No instance of this kind is known in North America. Even in the high Sierra in California nearly all of the families, genera, and species occur on the east slope as well as on the west, notwithstanding the great altitude this lofty range maintains for a considerable distance.‡ The explanation of the similarity or identity of the species on the two sides of all our mountain systems is that similar or identical climatic zones occur on both sides, between which avenues of communication exist or have existed by means of passes, either through the ranges themselves or at one end or the other. In their continuity, however, lofty mountain ranges do act as barriers to the spread of species from lower levels, but they do so indirectly by their effects upon climate—by interposing an arctic zone in which the species of lower latitudes can not live. On the other hand, this same arctic-alpine climate enables many polar species to thrive in regions two or three thousand miles south of their normal continental homes.

The great Himalaya has little or no influence in bringing about the really enormous differences that exist between the faunas and floras of the plains on its two sides, for these dissimilarities are due primarily to the great difference of temperature resulting from unequal base level, the Thibetan plateau on the north being several thousand feet higher than the plain on the south.

### THE SO-CALLED EASTERN, CENTRAL, AND WESTERN PROVINCES AND THE EVIDENCE ON WHICH THEY ARE BASED.

Wallace, in common with most recent writers, divides the United States into eastern, central, or Rocky mountain, and Pacific or Cali-

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* These genera are: *Didelphis, Dicotyles, Cariacus, Antilocapra, Cynomys, Reithrodontomys, Onychomys, Oryzomys, Sigmodon, Neotoma, Geomys, Thomomys, Dipodomys, Perodipus, Microdipodops, Perognathus, Heteromys, Felis, Urocyon, Procyon, Bassariscus, Taxidea, Conepatus, Mephitis, Spilogale, Notiosorex, Scalops, Corynorhinus, Euderma, Antrozous, Nycticejus, Molossus, Nyctinomous,* and *Otopterus.* Five of these genera have each a species reaching a short distance into the southern edge of the Boreal region, namely, *Cariacus, Neotoma, Felis, Procyon,* and *Mephitis.*

† Geog. Dist. of Animals, 1876, I, p. 6.

‡ For 320 kilometers (200 miles) the Sierra Nevada mountains maintain an elevation of 3,100 to 4,600 meters (12,000 to 15,000 feet).

fornian "sub-regions." He admits that the eastern division is characterized by but a single mammalian genus, namely, the star-nosed mole (*Condylura*).

In characterizing the so-called central or Rocky mountain sub-region, he states that the prong-horned antelope, the mountain goat, the the mountain sheep, and the prairie dog are peculiar to it, forgetting that the antelope ranges from the Mexican plateau northward over the Great plains and Great basin, and westward over much of California; that the mountain goat inh-bits British Columbia and the Cascade range as well as the Rocky mountains; that the mountain sheep is common in the High Sierra in California and ranges northward to the Arctic Circle in Alaska; leaving the prairie dog as the only one confined to the region.

The Pacific or "Californian sub-region" he defines as "the comparatively narrow strip of country between the Sierra Nevada and the Pacific. To the north it may include Vancouver's Island and the southern part of British Columbia." Under the head of the mammalia of this area, he enumerates eight genera as "not found in any other part of the Nearctic region," namely, *Macrotus*, *Antrozous*, *Urotrichus*, *Neosorex*, *Bassaris*, *Enhydra*, *Morunga*, and *Haploodon*. A more erroneous statement could hardly be made. Of the two pelagic genera, *Morunga* and *Enhydra* [= *Latax* ], the former does not enter the region at all and the latter barely reaches it; while of the non-pelagic genera three, *Macrotus* [= *Otopterus*], *Antrozous*, and *Bassaris* [= *Bassariscus*], range over the Sonoran region from Texas and the Mexican plateau across New Mexico, Arizona, and parts of southern Nevada and California, and the sub-genus *Neosorex* occurs over pretty much the whole of Boreal America from the Atlantic to the Pacific. The two remaining genera only are confined to the Californian division, namely, *Urotrichus* [= *Neurotrichus*] and *Haploodon* [=*Aplodontia*]. Both are isolated types, inhabiting the Pacific coast country from northern California to British Columbia (the latter having no near relative in any part of the world, the former closely related to genera now living in eastern Asia).

Hence it appears, so far as the mammalia are concerned, that these three supposed primary subdivisions of North America rest upon a misconception of fact, the Californian division possessing two peculiar genera, and the eastern and central divisions but a single peculiar genus each,—a quantity of difference it would be absurd to recognize as of sufficient weight to warrant the erection of zoö-geographical divisions.

In a communication already referred to (*North American Fauna*, No. 3, September, 1890) I stated the conclusion that the commonly accepted division of the United States into eastern, middle, and western provinces had no existence in nature, and that "the whole of extra-tropical

North America (the Nearctic region of Sclater and Wallace) consists of but two primary life regions; a boreal region, which is circumpolar, and a Sonoran or Mexican table-land region, which is unique." The so-called eastern province is mainly of Sonoran derivation, comprising the humid divisions of the Lower Sonoran and Upper Sonoran zones (Austro-riparian and Carolinian faunas), and of the transition or neutral belt, commonly known among ornithologists as the Alleghanian fauna. It contains also a southward extension of the boreal region along the Appalachian mountain system, mainly in the form of isolated islands.

The so-called central region in like manner is made up of a southward extension of the boreal region along the Rocky mountain plateau, inclosed between two northward prolongations of the arid Sonoran, the one occupying the Great plains, the other the Great basin.

The so-called Pacific or western province consists of a southward extension of the boreal region, which finally bifurcates, sending a long arm south over the Cascade range and the Sierra Nevada, and a secondary and shorter arm along the Pacific coast, north of San Francisco, together with a Sonoran element, which covers nearly the whole southern part of the state, and reaches north in the San Joaquin and Sacramento valleys.

### PALÆARCTIC AND NEARCTIC REGIONS.

It is no part of the purpose of the present address to discuss the distribution of life outside of our own continent, but it so happens that the Boreal element in America resembles that of Eurasia so closely that in the judgment of many eminent authorities the two constitute but a single primary region, a view in which I heartily concur. This arrangement is antagonistic to that proposed by Sclater * in 1857, and adopted with slight modification by Wallace. Sclater considers the whole of extra-tropical North America as constituting a single region, upon which he bestowed the name *Nearctic*, in contra-distinction to the corresponding part of Eurasia, which he named *Palæarctic*, believing the two to be distinct primary regions.

Wallace, the great champion of Sclater's Palæarctic and Nearctic regions, says of the former in his most recent work on geographic distribution: "Taking first the mammalia, we find this region is distinguished by its possession of the entire family of *Talpidæ* or Moles, consisting of 8 genera and 16 species, all of which are confined to it, except one, which is found in northwest America, and two which extend to Assam and Formosa." (*Island Life*, 1880, 41.) How he could have made such an erroneous statement is hard to understand, in view of the well known fact that 3 genera of moles inhabit eastern North America and 2 the Pacific coast region; and it is the more strange

* *Journ. Linn. Soc.* (Zoöl.) (for 1857), 1858, II, 130–145; and again, with some alterations, in *Ibis*, 1891, sixth series, III, 514–557.

since on another page of the same work he states that there are three peculiar genera of moles in North America.*

He states further: "Among carnivorous animals the lynxes (nine species) and the badgers (two species) are peculiar to it [the Palæarctic region] in the old world, while in the new the lynxes are found only in the colder regions of North America" (*Island Life*, 1880, 41), thus implying that there are no badgers in North America, and ignoring the presence of lynxes all along the southern border of the United States from Florida and Texas to southern California. Continuing, he mentions a number of groups which, he says, "have only a few species elsewhere." Among these are the "voles, dormice, and pikas." Pikas inhabit the mountains of western Canada and range south in the Cascades and High Sierra to southern California, and in the Rocky Mountains to Colorado. They have been reported also from the high mountains of Lower California in Mexico. The group of voles or *Arvicolinæ*, exclusive of the lemmings, is represented in Boreal North America by not less than four genera, five sub-genera, and nearly fifty species. It is only fair to add, however, that some of these have been described since Wallace's book was written.

"The Nearctic region is so similar to the Palæarctic in position and climate," he admits, "and the two so closely approach each other at Bering Strait that we can not wonder at their being a certain amount of similarity between them,—a similarity which some naturalists have so far over-estimated as to think that the two regions ought to be united." After enumerating a number of mammals common to the two he goes on to say: "We undoubtedly find a very close resemblance between the two regions, and if this were all, we should have great difficulty in separating them. But along with these we find another set of mammals, not quite so conspicuous but nevertheless very important. We have first, three peculiar genera of moles, one of which, the star-nosed mole, is a most extraordinary creature, quite unlike anything else. Then there are three genera of the weasel family, including the well-known skunk (*Mephitis*), all quite different from eastern forms. Then we come to a peculiar family of carnivora, the raccoons, very distinct from anything in Europe or Asia; and in the Rocky Mountains we find the prong-horned antelope (*Antilocapra*) and the mountain goat of the trappers (Aplocerus [=*Mazama*]), both peculiar genera. Coming to the rodents, we find that the mice of America differ in some dental peculiarities from those of the rest of the world, and thus form several

* In his earlier work he says: "*Condylura* (one species), the star-nosed mole, inhabits eastern North America from Nova Scotia to Pennsylvania; *Scapanus* (two species) ranges across from New York to San Francisco; *Scalops* (three species), the shrew moles, range from Mexico to the Great Lakes. - - - *Urotrichus* is a shrew-like mole which inhabits Japan, and a second species has been discovered in the mountains of British Columbia." (*Geog. Dist. of Animals*, 1876, II, 190.)

distinct genera; the jumping mouse (*Xapus* [=*Zapus*]) is a peculiar form of the jerboa family; and then we come to the pouched rats (*Geomyidæ*), a very curious family consisting of four genera and nineteen species, peculiar to North America, though not confined to the Nearctic region. The prairie dogs (*Cynomys*), the tree porcupine (*Erethizon*), the curious sewellel (*Haploodon* [=*Aplodontia*]), and the opossum (*Didelphis*) complete the list of peculiar mammalia which distinguish the northern region of the New World from that of the Old." (*Island Life*, p. 48.)

As already shown in an earlier part of the present essay, most of these genera and several of the families belong to the austral or Sonoran region and have no place in the Boreal fauna—the only one that can be compared with the fauna of northern Eurasia. As a matter of fact, eighty-one genera of non-pelagic mammals are now recognized in "extra-tropical" North America—the so-called Nearctic region. Of this number forty-one are found in no other part of the world.* These genera are enumerated in the following table, which brings out the important fact that no less than thirty-two, or 78 per cent, are of Sonoran or austral origin, while only nine, or 22 per cent, are of Boreal origin. Of these nine genera now confined to North America, *Ovibos* inhabited polar Eurasia in Pleistocene times; *Neurotrichus* is not recognized by Flower and Lydekker as more than sub-generically separable from *Urotrichus* of Japan, and *Synaptomys* is not known except from the Transition zone of the United States and is here classed as Boreal because of its close relationship to the trans-continental Boreal genus *Myodes*. Omitting these three, Boreal North America has but six genera of mammals not known from Boreal Eurasia.

*Peculiar genera of mammals inhabiting North America north of Mexico.*

OF BOREAL ORIGIN.

| | | | |
|---|---|---|---|
| Mazama. | Fiber. | Zapus. | Neurotrichus. |
| Ovibos. | Synaptomys. | Erethizon. | Condylura. |
| Aplodontia. | | | |

OF SONORAN ORIGIN.

| | | | |
|---|---|---|---|
| Cariacus. | Neotoma. | Urocyon. | Scapanus. |
| Antilocapra. | Thomomys. | Bassariscus. | Blarina. |
| Cynomys. | Geomys. | Taxidea. | Antrozous. |
| Reithrodontomys. | Dipodomys. | Conepatus. | Nycticejus. |
| Sitomys. | Perodipus. | Mephitis. | Otopterus. |
| Oryzomys. | Microdipodops. | Spilogale. | Corynorhinus. |
| Onychomys. | Perognathus. | Notiosorex. | Euderma. |
| Sigmodon. | Heteromys. | Scalops. | Atalapha. |

* The intrusive genera *Didelphis*, *Tatusia*, *Dicotyles*, *Procyon*, *Nasua*, and *Molossus*, which are clearly of South American origin, are not here included.

On the other hand, out of the thirty-one Boreal genera of North American mammals the following, twenty-four genera or 77 per cent, are common to Boreal America and Boreal Eurasia:

| | | | |
|---|---|---|---|
| Cervus. | Arctomys. | Cuniculus. | Lutreola. |
| Rangfer. | Castor. | Lagomys. | Putorius. |
| Alce. | Phenacomys. | Vulpes. | Mustela. |
| Ovis. | Evotomys. | Ursus. | Gulo. |
| Bison. | Arvicola. | Thalarctos. | Sorex. |
| Tamias. | Myodes. | Latax. | Urotrichus.* |

In addition to the foregoing genera, which are clearly of Boreal origin, the following twelve genera of more extended range are also common to the two continents:

| | | | |
|---|---|---|---|
| Sciuropterus. | Lepus. | Felis. | Vespertilio. |
| Sciurus. | Canis. | Lynx. | Plecotus.† |
| Spermophilus. | Lutra. | Vesperugo. | Nyctinomus. |

Most of these genera are known to be of great antiquity, their remains having been found in Miocene strata, and it is probable that the others belong to the same category, but have thus far escaped detection, owing to their very small size. All of them attain their maximum development and numbers in the Sonoran region in America and the analogue of the Sonoran in Eurasia; but by reason of the great length of time that has elapsed since they came into existence some of their representatives have become acclimated to a wide range of climatic conditions.

Dr. John L. Le Conte, in his report on the Coleoptera of Lake Superior, said: "The entomologist can not fail to be struck with two very remarkable characters displayed by the insect fauna of these northern regions. First, the entire absence of all those groups which are *peculiar* to the American continent [*i. e.*, Sonoran and Tropical groups]. - - - The few new genera which I have ventured to establish are not to be regarded as exceptions. They are all closely allied to European forms, and by no means members of groups exclusively American.

"Secondly, the deficiency caused by the disappearance of characteristic forms is obviated by a large increase of the members of genera feebly represented in the more temperate regions, and also by the introduction of many genera heretofore regarded as confined to the northern part of Europe and Asia. Among these latter are many species which can be distinguished from their foreign analogues only by the most careful examination. This parallelism is sometimes most exact, run-

* As stated above, Flower and Lydekker do not recognize the American animal as generically distinct from *Urotrichus*. While I agree with Dobson in according it generic rank, it is convenient, in studying the origin of groups, to bring together such closely related types.

† The American species of *Plecotus* are separated generally by Dr. Harrison Allen under the name *Corynorhinus*, which is adopted by the writer. The more comprehensive name *Plecotus* is here used for the reason just stated under *Urotrichus*.

ning not merely through the genera, but even through the respective species of which they are composed." (*Lake Superior*, 1850, 239, 240.)

W. F. Kirby, in a paper "On the Geographical Distribution of the Diurnal Lepidoptera as compared with that of Birds," states: "Had I been dealing with Lepidoptera only, I would certainly have united Dr. Sclater's 'Palæarctic region' and 'Nearctic region;' for although the species of North American Rhopalocera are seldom identical with those of northern Asia and Europe, still the genera are the same with scarcely an exception, except a few representatives of South American genera, which have no more right to be considered Nearctic species than the similar chance representatives of African forms in north Africa or southwest Europe, or of Indian forms in southeast Europe have to be considered Palæarctic species." (*Journ. Linnean Soc., London. Zoöl.*, 1873, 432.)

It now becomes evident that the so-called Palæarctic and Nearctic regions are the result, in each case, of confounding and combining two wholly distinct regions—the Boreal with the Sonoran in America and the Boreal with the analogue of the Sonoran in Eurasia. Eliminating these austral elements as wholly foreign to the region to which they have been so persistently attached, there remains a single great circum-polar Boreal region characterized by a remarkably homogeneous fauna, covering the northern parts of America and Eurasia.

Cope has shown that the chief differences between Boreal America and Boreal Eurasia are found among the fishes and batrachians,—animals living wholly or in part in water. Now, it can not be insisted too strongly that while the chief factor in the distribution of aquatic animals and plants is temperature, as has been long acknowledged, yet from the very nature of the case the resulting life regions must be different, the one supplementing or being the complement of the other; for, water being the medium in which the species live, the bodies of water with their prolongations and extensions, as bays, rivers, and lakes, must be studied as entities, just as we study a continent with its peninsulas and outlying islands, the means of access to a given body of water being the principal factor in determining the water area to which its aquatic life belongs. And it should be remarked that aquatic mammals (as seals and cetaceans), and aquatic birds (as ducks and gulls), conform in the main to the laws and areas of aquatic distribution, and should not be taken into account in studying the distribution of terrestrial forms of life.

Gill has said with much truth: "There appears to be a total want of correlation between the inland and marine faunas, and a positive incongruity, and even contrast, between the two." (*Proc. Biol. Soc. Wash.*, 1884, II, 32.)

## PRINCIPLES ON WHICH BIO-GEOGRAPHIC REGIONS SHOULD BE ESTABLISHED.

Wallace, in writing of the principles on which zoölogical regions should be formed, expresses the opinion that "convenience, intelligibility, and custom should largely guide us." But I quite agree with America's most distinguished and philosophic writer on distribution, Dr. J. A. Allen, that in marking off the life regions and sub-regions of the earth, truth should not be sacrificed to convenience; and I see no reason why a homogeneous circum-polar fauna of great geographic extent should be split up into primary regions possessing comparatively few peculiar types simply because a water separation happens to exist in the present geologic period; nor is it evident why one of the resulting feeble divisions should be granted higher rank than a region of much less geographic extent comprising several times as many peculiar types. Hence the divisions here recognized, and the rank assigned them, are based as far as possible upon the relative numbers of distinctive types of mammals, birds, reptiles, and plants they contain, with due reference to the steady multiplication of species, genera, and higher groups from the poles toward the tropics. Mammals have been chiefly used as illustrations because they answer the purpose better than any other single group, and because it is clearly impossible in a brief essay of this character to enumerate such a multitude of forms as would be necessary were equal consideration accorded to each class.

# THE CORBIN GAME PARK.*

By JOHN R. andolph SPEARS.

## I.

Here is an interesting study in human nature; a picture of the inception and growth of an enterprise of great moment to the naturalist and the sportsman, and of interest to everyone. Six years ago a friend presented to Austin Corbin, the well-known railroad man, a few young deer. Mr Corbin accepted them, and having a great country seat that included many acres of woods as well as cleared fields out on Long Island, he caused a part of the woods to be suitably fenced, and turned the deer into the inclosure. Mr. Corbin, at that time, was neither a sportsman nor a naturalist, in the sense in which these terms are generally understood. He had no especial interest in wild animals of any kind. Nevertheless, as a lad he had lived on a farm in New Hampshire, among the foothills of the White Mountains, and had trapped woodchucks, and shot partridges and chased foxes, and the good healthy delights of those days lingered in his memory. Small wonder then that the gentle pets his friend had given to him won their way into his affections from the moment they became his. It was a new pleasure—something he had never known before,—to go and watch their graceful motions and gaze upon the beauty of their forms. Moreover, Mr. Corbin had a son, and Austin junior was as much delighted with the pets as his father.

There was ample room on the Long Island farm for more than the few deer, and the Corbins decided that more should be had. This led to the examination of sundry books on the subject of deer culture, if one may use the term, books like Judge Caton's, for instance, while the *Forest and Stream*, and other periodicals were necessarily read regularly. Certainly the love of nature grows with what it feeds upon, if any emotion of the heart does. If deer could be kept, why not deer's cousins, the elk, the moose, the antelope, and the buffalo,—especially the buffalo?

* From *Forest and Stream*, for March 12, 1891, and May 26, 1892.

Mr. Corbin had lived in Iowa when a young man, and in the days when the herds of buffalo on the plains of Nebraska, Kansas, and Texas numbered untold thousands. It was a great pity that such noble animals were likely to become extinct, and the Corbins determined to join in the effort to perpetuate the species. They had begun with a few deer, and they added the elk, the antelope, and the buffalo, and then it became apparent that the Long Island estate was too small for the proper care of these animals, or at least for the care which the owners desired to give them.

It is to be particularly noticed that the Long Island estate was not suited to the sort of care that the Corbins wished the animals to have. From caring for the few pets had grown the desire to rear herds of these animals under such conditions of freedom as would leave them with all their natural characteristics. A pet deer was beautiful, but it was not the deer of the wild woods after all. A pure bred buffalo in a barn-yard was in fact a buffalo, but he was too much like a Durham bull to be perfectly satisfactory. On the Long Island farm the animals could scarcely become anything more than pets.

So the thoughts of the elder Corbin went back to the days of his youth and the foothills of the White Mountains. As most of our readers know, there is plenty of land in New Hampshire that is just as wild now as it was when Hudson first looked on the ground where the statue of liberty now stands. There was a deal of it in Sullivan County, perhaps not the wildest in the State, but certainly a plenty of unbroken forest that covered hills and valleys and surrounded little lakes, forests of birch and beech, and maple and pine, and spruce and hemlock, and balsam,—forests beautiful and fragrant enough to give a city man the heartache when he thinks of them.

Mr. Corbin determined to buy from 20,000 to 30,000 acres of these hills and valleys and there establish a park for his new-found four-footed friends in which they would find the conditions as near those as possible to which they were best suited. Mr. Corbin eventually got 22,000 acres in one tract.

The next thing was to fence it, and only those who have tried building elk-tight fences can appreciate the job. Here was a tract of over 35 square miles of land to inclose. They started out with a wire net 6 feet high, secured to stout posts 10 feet apart. Above the net they strung ten lines of barbed wire, and that made a right good fence. But when 18 miles had been erected they abandoned the wire net and used barbed wire only for the rest of the way. That was cheaper and just as good. It is not uninteresting to note that the fencing cost $74,000.

In all, nine gates are to be placed in this fence, with a keeper's lodge at each gate, something made necessary by the presence in every community of the skulking lout who will steal or destroy the property of the well-to-do, and especially such property as this fence will inclose.

Mr. Corbin is sure his park will not in any way interfere with the rights of legitimate sportsmen.

Here is this tract of woodland with only enough cleared land on it to afford meadows over which the animals would like to wander at times, are gathered 25 buffalo, 60 elk, over 70 deer, half a dozen each of caribou and antelope, 18 wild boars imported from Germany, and an unknown number of moose,—perhaps a dozen. He had 4 reindeer brought from Labrador, but all died. He expects to have a community of beavers, for the lakes and streams of the park are admirably adapted for these beautiful animals.

Quite as interesting as any description of the park and its inhabitants is the story of the gathering of the specimens. It is too long to tell in full, but room remains for enough. The agent employed to gather a large part of the animals from Canada was Thomas H. Ryan, who has served Mr. Corbin in a number of capacities for the past twelve years. Along in October last Mr. Ryan was commissioned to go to Canada to see what could be done abont getting "any wild animals there except bears, panthers, wolves, and foxes."

At Sherbrooke he met a friendly newspaper man who said one Dan. Ball, of Megantic, knew all about the deer of that country, and so to Megantic posted Mr. Ryan. He met Ball and found him able and willing to get the deer.

Mr. Ryan went 50 miles to North Bay, 200 miles west, and from there to Mattawa, on the verge of a region where moose abound, deer are plentiful, and beaver possible to obtain alive. A contract was made with a trapper, whose name Mr. Ryan does not wish to mention, for a supply of all these animals—at least twenty of each if that number be possible.

Meantime Dan Ball had gone to work at Megantic by selecting a few friends and looking over the woods to see where the deer were yarding. Along in December the snow became 5 feet deep in the woods, and Dan knew of one yard where at least 300 deer were gathered together.

Then he and six others went on snowshoes, with buckskin thongs, and one gun loaded with powder only. Locating a bunch of deer in a thicket, six of the men crept up as near as possible to the leeward without alarming them. Then the seventh came tearing down with the wind and with a wild yell and the discharge of the gun scattered the bunch like a flock quails before a cur pup. Some of the fleeing beauties plumped into the snow, that was so deep and so fluffy that they sank out of sight at the first struggle, nor could they escape till Dan and his friends kindly lent a hand. In all a dozen were captured thus, and with legs bound with soft leather thongs were carried to an old shanty in the woods some distance from Megantic.

In January Mr. Ryan went away to bring the deer to the park in New Hampshire. Megantic is on the Canadian Pacific road. A box

car was sent to a siding formerly used by a lumber mill, and there carpeted with hay, straw, and a good supply of browse. The ends were then partitioned off from the space between the doors by means of poles, and within the spaces thus formed the deer were placed, being simply lifted in. They had been kept in the meantime in the old mill unbound.

With Dan Ball to look after and especially to water the deer the car was hauled to Newport, Vt., the location of the United States customs office.

The deer were passed duty free, and were sent on to Newport, N. H., by the way of Concord, nearly 100 miles farther than necessary. The extra ride proved disastrous, for one deer died *en route*, and two after arrival. The nine are now as well and frisky as when in their native forests.

The buffalo in the park came originally from Montana, but were purchased of a Minnesota man. The moose, elk, and caribou came from Minnesota also, and were captured along the Canadian border.

Among the interesting experiences in the transportation of the animals for this park may be mentioned these: Moose have been carried 2,000 miles in four days without apparent injury. The last consignment included sixteen moose, three deer, and one caribou. All arrived in good condition, but eight moose died afterwards, because, it is thought, of the change in their diet or water, or both. On one occasion when thirty deer were en route, a collision with another train killed twenty-two of them outright, and four more died afterwards.

It is noticed that the largest deer most easily succumb to railroad travel. None of the animals ever eat or sleep while the car is in motion. On a side track they will eat a little. There seems to be more danger of their suffering from heat in a box car than from cold, but the worst trouble is in the jerking to and fro of the car when the train is stopping or starting. They are fed barley, corn, bran, and hay. In the woods they are expected to live as they would naturally, but places will be established where feed will be left for them, so that none shall lack.

Beginning with a few pet deer in a paddock, the Corbins now have a private zoölogical garden where, if at any such place in the world, the animals on hand can be seen and studied under natural conditions. What it will be in the future Mr. Corbin can not say, but that he will, as fast as convenient to do so, add all the animals of the world that can live there harmoniously need not be doubted. His outlay up to the completing of the park is not far from $400,000. Some of his friends say he is likely to spend half as much more on it and make of it a place to fairly delight the naturalist. They say that the work of Judge Caton will be supplemented and added to, by that to be done at the Corbin park, to the great benefit of all investigators into the habits of wild animals.

II.

In the issue of March 12, 1891, we published a very interesting account of Mr. Austin Corbin's game park in New Hampshire, telling how Mr. Corbin was led into the enterprise, and also giving an account of how the first animals used in stocking the park were secured. Since then we have obtained the following information of the present state of affairs in the park, chiefly in relation to the breeding of the animals in their new environment—it can hardly be called captivity, when the animals are at liberty to wander at their own sweet will over 28,000 acres of woodland, hill, and valley.

In this respect of breeding the park has proved a great success. All the animals seem to take kindly to their new surroundings, and already their numbers are being materially increased by births. Of the twenty-two buffalo which were put in about a year ago, eight of the cows are now in calf, and two young have been added to the herd. The elk, which bred to a limited extent on Mr. Corbin's Long Island estate, have found their mountainous New Hampshire home more to their liking, and have already increased 50 per cent. Next to the elk the most accurate count has been kept of the moose, who, unlike their gregarious brethren, go in pairs during the rutting season. It was at first feared that these unusually retiring animals would not breed in the park, but it has been ascertained that six of the cows are now with calf. There are upward of sixty moose in the park and they make a much wider range in travelling than the elk, which keep pretty well to one locality where there is considerable brush and small growth, and no doubt abundant feed.

The agent who was instrumental in securing for Mr. Corbin the first denizens of the park has the head of a particularly fine moose in his possession. The unmounted head weighed 300 pounds, and the horns, which show eleven points, have a span of about 5 feet. This head was bought of an Indian in Mattawa, and is said to be the last green head taken out of Ontario previous to the passing of the law forbidding the killing of moose.

To come back to figures, the wild boars, imported from Germany September a year ago, have been seen a number of times lately. They have evidently gained by natural increase, and must be quick travellers, as three or four herds have been reported in different localities at nearly the same time by the game-keepers. The old animals have grown considerably, and are wonderfully fleet of foot, for unlike their cousin, the domestic hog, they do not fatten. As far as can be ascertained, all the other animals, including the several varieties of deer, have multiplied considerably, and their change of habitat and the fact that the big fence occasionally checks their extended wanderings, does not seem to cast any blight on the even tenor of their lives.

Included in the park are two ponds of 20 and 30 acres, respectively, and probably 100 miles of streams. The ponds were cleaned out last

year and many eels and other varieties of cannibalistic fish destroyed, and now the ponds and streams are all stocked with trout.

While in London, two years since, Mr. Corbin purchased 20,000 hawthorn trees. Four thousand of these have been planted this spring.

FIG. 1.—View of Buffalo, in the CORBIN Game Park.

They are for the purpose of forming a hedge strong enough to prevent the buffalo and other large animals from getting out. This tree, of which there are two varieties, the white and black, is used very extensively for inclosing the game parks of England and France. It grows from 8 to 10 feet in height, and is the toughest and strongest tree that can be found, making, with its interlocking and elastic branches, a hedge that would resist a battering ram. The trees are being planted inside the big fence of barbed and woven wire, and will eventually take its place when the latter becomes weakened through rust and exposure.

There will be no hunting in the park at present, though in future years, when the animals have multiplied beyond the resources of their domain, it is possible that Mr. Corbin may adopt this means of thinning them out. It is sufficient to say that the park is not designed for hunting. Similarly, it is not primarily intended for scientific research into the habits, breeding, etc., of the various animals, though it is safe to say that it would yield rich returns in this direction.

The development of Mr. Corbin's game park enterprise is being watched with decided interest by sportsmen and naturalists. It happens that the present article has been prepared just in time to supply additional information on the subject sought by the directors of the new National Zoölogical Garden in Washington. Success in New Hampshire, when it shall have been demonstrated beyond the peradventure of a doubt, will prompt similar enterprises in other parts of the country. While much interest is felt in the introduction of foreign species, Americans are naturally most concerned with the successful conservation of bands of American big game, the elk and the antelope and the buffalo. Of the unfamiliar picture these great animals present, grouped on a New Hampshire hilltop, our cut, from a photograph, gives excellent illustration. May these wild creatures yet feed on a thousand hills of the New England and other Eastern States, and on the game preserves of the west!

Besides the great New Hampshire park, Mr. Corbin has two other game preserves. On his Long Island estate he now has 21 elk and about 18 deer, and at Manhattan Beach he has 25 elk. At the latter place he has 10 acres inclosed with an open wire fence. There will soon be dug here a large pond, which will be filled with salt water from the tides of Sheepshead Bay. In this pond are to be a dozen seals and 10 sea lions. The former are now on their way from St. Johns, Newfoundland, and the latter are making their long journey from the Pacific coast. Later in the summer a number of other animals will be added to the inclosure.

# THE HOME OF THE TROGLODYTES.*

By E.rnest T.heodore Hamy.

The ancients had a vague knowledge of a people inhabiting certain districts of northern Africa, who were remarkable for the custom, which they had in common, of making their habitations in the depths of the earth. These were the Troglodytes.

A portion of the sea-coast of Erythræum Mare (Red Sea) owed the name of Troglodytic Ethiopia to certain of these barbarians; others occupied a territory adjacent to the mountains which rise in the southern part of Fezzan, while others, much farther to the west, inhabited an undulating region in which there is recognized the chain which surrounds the lower extremity of Little Syria.

The accounts of these curious people, as given by ancient writers, always represent them as constructing their dwellings under ground; as being hunters of such activity and skill that they take their game while in pursuit, living for the most part however on the flesh of serpents and lizards. They are described as being poor and indifferent to their own interests, having no trade except in carbuncles, for which however they were merely agents. Their language differed entirely from that of any other people, it being compared by Herodotus to the strident cry of the bat.

These summary accounts, incoherent and sometimes fantastic, have had the effect of rendering most modern historians of African geography incredulous as to their truth. These extraordinary beings have been ordinarily banished to a world of the imagination, the species of whom antiquity has so largely multiplied even to the confines of known countries. Reliable travellers came however in their turn to discover in the very same regions where the ancients had located their Troglodytes, important tribes, living like them in subterranean abodes, natural or artificial.

The English Captain Lyons described in 1821, during a four days' march to the southwest of Tripoli, through a district mentioned by

*Read at the annual public meeting of the five Academies of the Institute of France, October 24, 1891. (From *L'Anthropologie*, Sept.-Oct., 1891; vol. II, pp. 529-536.)

Pomponius Mela and by Pliny, a certain village of Beni-Abbas, deeply hollowed out of the sandy clay or calcareous rock. The French Consul Delaporte, the Egyptian Sheik, Mohammed-Ibn-Omar-el-Tounsy, and others, in confirming this discovery have generalized it to the entire region of Ghârian.

In 1869, Nachtigal found hidden in the valley of Tao, in the heart of Thibet, the caves of the Toubous, direct descendants of the Ethiopian Troglodytes, whom Herodotus represented as the victims of the Garamantes, the ancient inhabitants of Fezzan. Thirty years later our soldiers, penetrating into the massive mountains which rise to the southwest of Gabes, and at Douirat and Nefouça are connected with Ghârian, came upon a dozen villages excavated from the ancient alluvium of the plateaus of Matmata and Toujane, containing as many as 4,000 inhabitants. Distinguished officers, such as the commander, Rébillet; learned naturalists, like Letourneux, have since that time visited this country, and I, in my turn, have traversed it in the course of a voyage of inquiry.* If I saw few serpents and lizards, and still fewer carbuncles in the dark dwellings of Matmata, of Hadeje, or of Beni-Zelten; if I did not hear proceed from the mouth of the Caliphs, who received me so cordially, the strident tones which the historians and classical geographers have ascribed to their ancestors, I have at least been able to make some observations which are of a nature to throw light upon the interpretations of certain passages in the writers of antiquity. I gathered at the same time new data for the study of those ethical survivals, which day by day are playing a more important part in history and anthropology.

## I.

The journey from the coast of Syria to the interior valleys peopled by the Troglodytes is a short but rough one. It is necessary to cross the arid and stony desert of Araad, then to make the painful ascent of the bed of one of the dried-up torrents, which has worn its way through the steep cliff of Mount Demer.

The approach to these subterranean villages is most accessible from the west. In ascending the acropolises of Zenâtia, the contrast between the characteristics of these two neighboring tribes is strikingly evident. They belong to the same ethnic group, but each is faithfully devoted to its own traditional customs. The Zenati construct their villages according to the architectural rules which governed the builders of the ancient Berber cities, ruins of which I have found in central Tunis, between Dar-el-Bey and Kairouan. They are in reality intrenched camps, formed by walls of bare stones, with occasional openings, surmounted in the rear by other walls, parallel and strengthened by semi-circular turns, which protect the entrance to the lanes. The Matmati, on the

*I had for a travelling companion the engineer, Monsieur J. E. de la Croix, who was studying the geology of the region.

contrary, like the ancient Troglodytes, excavate their dwellings, scattered here and there without order, from the compact allivium which the rains have long since formed in the depressions of the valley.

To the rear are the rocky summits where rise the somber Zenâtian redoubts, Tamezret, Zeraoua, etc., while in front is the open, undulating valley where there is nothing, at first sight, to reveal the presence of man. A narrow neck, guarded by a small fort of rough stones, marks the limit of the two territories. The descent is made slowly by a steep inclination following a ravine which has long since been worn by the floods. The hardness and depth of the slimy bank suggest to the unprejudiced mind the possibility of here digging out one's habitation. It is a continuous descent; the valley broadens, the horizon becomes visible, a vast extent of land is gradually perceived, and not a sound, not a movement to suggest the approach to a populous village. Below there however to the right is the Gelaâ Matmata, which appears to the eye with its abrupt descent and its extensive terrace like a natural fortress, where, many a time during the course of a turbulent history, the natives have found a refuge. To the left is the west Matmata, outlining the yellowish course of its dried bed, dotted here and there with stattered olive trees. Matmata Bled Kebira, the large town of Matmatia, is in truth at our feet without our having perceived it. Let us approach. Traces of its presence become gradually apparent. Elevations and corresponding depressions in the land become clearly defined, and the white Koubba of the Mohammedan priest, Sida-Mouça appears at the turning of the footpath informing us that these ancient people, with their strange manners, whom we wish to approach, have submitted to the destructive influence of Islam, and have in consequence preserved only a few of those valuable survivals which we are so desirous of studying.

In Egypt, among the wretched dwellings in mutilated pyramids, and in the double dovecots which remind one of the old Pylons; in the acropolises of Zenâtia at Gharian and Kabylie, in a word, over the whole of northern Africa, the *Koubba* of the priest, the minaret of the mosque, symbols of triumphant Mohammedanism, strike the archæologist and ethnologist as something abnormal, and I may say entirely out of place. These rural constructions, unsightly in themselves, and incongruous when placed side by side with those of the natives, in the midst of which they are conspicuous on account of their form and color, disturb the harmony of the landscape, recalling at the same time the cruel struggles, by fire and arms, for conquest and conversion to the religion of the conquerers. The abrupt cliffs of Mount Demer were not able to arrest the Hillalien (?) invasion, and Matmati, the Troglodyte, has been since then a good Mussulman.

Two other *Koubbas* appear, then a square white house, the abode of the religious chief, then the *dar* of the civil and military chief, the Caliph Ali-Ould-Kaïd-Ahmed.

This *dar* is composed of five parallel chambers in masonry, which, beyond the first glance, are not Troglodytic in character. A small quantity of loose earth has been carried for appearance sake onto the terrace which surmounts the structure. In this detail the residence of Ali—Berber in style although strongly Arabized—is that of the great semi-sedentary chiefs, which one meets with more especially in the interior of Tunis.

One of the last surface structures is an old cistern, of which the partially demolished arches bring to mind, by their form and construction, those of Malga, at Carthage.

The remainder of the village, which extends over 4 kilometers and contains more than 2,000 inhabitants, is entirely under-ground. The *dar* even, which shelters us, covers a vast cave, descent into which is made by a semi-circular declivity. It is a part of the dwelling of the ancient chiefs, constructed, Ali informs us, in the time of the Romans, which, to the good Caliph, seemed to stand for the most remote period. The excavators who executed this ancient work had to penetrate first through the calcareous clay, which forms the soil of the whole valley; then through a pebbly conglomerate, and finally through a quarry of hard millstone, which forms the floor of the grotto. A second excavation, of more recent origin, is dug out of the clay a little higher and to the right of the first. This serves as a stable for the horses of Ali.

Dwellings, stables, cattle sheds, workshops, and factories, everything in the village of Matmatia, are likewise excavated from the clay. In one instance the descent is made, as in the caves of the abode of the Caliphs, by means of an incline more or less perpendicular, and lighted from without; in another it is necessary to seek an entrance through a tunnel, which terminates, after several windings, in an interior court, more or less regular and lighted from above at the summit of the alluvial peak of the elevation from which the dwelling has been dug.

A little factory, which we can enter, gives a good idea of the manner in which work is carried on by tradition among the excavators of Matmatia. It is an oil factory, composed of three compartments, the first of which commands the other two and is lighted by an arched door, to which a straight flight of steps gives access. The two deep chambers remain unfinished, a wall, consisting of a mass of earth, dividing one from the other. The interior was dug out with a pick-axe, forming arches, and there remain cubes sufficiently large to support the center. The largest room contained the mill and its accessories, resembling closely the apparatus used all over the Berber states.

The entrance to this primitive factory is ornamented with a row of uncemented stones around the aperture forming the entrance. The detail of this ornamentation recalls the custom among ancient builders of covering the front of their subterranean dwellings with a facing of stones, in more or less regular lines. Not far from the *dar*, a sort of palace (belonging to a very remote period and for the most part in ruins, where I

have been able to make some researches,) contains in its interior court façades, completely provided with walls where deep vaulted chambers open on two elevations. The dwelling of the chief, the stables, and the cattle-sheds formerly occupied the ground floor. The *souks* or store-rooms were constructed in stories, to climb to which one clings to large stones jutting out from the wall.

If the façade presents an ornamentation of stones, nothing is seen in the interior but calcareous rock and a sort of loam, still showing the ridges made by the irregular strokes of the pick-axe of the ancient builder. Neither stone, wood, nor iron appears, only the soil of a reddish or yellowish gray, dry and hard, in which rare snail shells are found here and there. If a ring, upon which to hang a lamp or to which to fasten a horse's halter is required, these shells are utilized, being placed in the most convenient and conspicuous point in the room or stable. Niches take the place of cupboards, and benches along the side wall serve as beds and chairs.

These apartments, like all the others which we saw among the Troglodytes, are quite regularly vaulted, although the arches are keel-shaped, the sides being slightly curved and the extremities perceptibly drawn together. We are reminded of an old boat, turned upside down, keel in air, lying upon the sea-shore, under which the poor gatherer or waif may find a shelter.

In thus recognizing nautical forms in the most essential lines of the architecture of the Troglodytes, I suddenly recollect the rustic habitations (*mapalia*) of which Sallust speaks in the eighteenth chapter of his classical work on the Jugurthan war. In summing up the traditions of the Province, which he governed, and which he must have thoroughly known, he mentions the death of Hercules, and the dispersion of his army composed of various nations. Medes, Persians, Armenians crossed over to Africa in their ships and occupied the seacoast. The Persians are the most remote from the ocean, the most eastern, and consequently occupy that region adjoining Syria; and since they do not find building material upon this inhospitable shore, and the vastness of the sea and ignorance of the language of their neighbors deprive them of the means of procuring such material by purchase or exchange, they have built for themselves shelters out of the hulls of their ships; and Sallust adds that the buildings of their descendants, called *mapalia*, oblong constructions with curved sides, resemble the keels of ships, the abodes of their ancestors.

Not so very long ago, when the ethnography of Africa was practically unknown, an attempt was made to explain the survivals indicated by the Roman historian by likening the *mapalia* which he describes to the tents of the wandering tribes of the lofty table-lands of the Atlas. In history, as in government, the Berber and the Arab are confounded, to the great prejudice of our African policy, and in the same manner the commentators of Sallust ignored the essential differences which

exist between the solid buildings of the ancient inhabitants of the soil and the temporary movable abodes of the shepherds, whose migration to Magreb is comparatively recent. The true *mapalia* are keel-shaped constructions, long, narrow, and low, of which the *ksours* of Mettamer and of Medennie in Araad represent the most perfect type, and which our Troglodytes of Matmata, d'Hadeje, etc., have adapted to their special needs.

## II.

Sallust, in ending his chaper on ethnology, describes the strangers whom legend brings to the shores of Africa as mingling with the native Getules, and increasing rapidly, from which alliances have sprung the great nation of the Numidians, soon spreading over all the territory about Carthage.

The uncertainty as to origin, thus attributed by tradition to the Numidians, manifests itself even in our day in regard to the Berbers of Tunis in general, and particularly among those of the mountains of the south. A special ethnical type, of which the large island of Djerba is the principal center of habitation, here comes in contact with another type, no less characteristic, which predominates in the Djerid. The type of the Djerabi, which corresponds to the foreign population which Sallust represented as landing on the shore in the vicinity of Syria, is distinguished, at the first glance, by a very clear complexion of a dead white, or else slightly bronzed, relative shortness of the head, and roundness of the face; the nose is straight, the lips thin, the chin rounded. The type of the Djeridi, descendants of the ancient Getules, is characterized on the contrary by dark coloring, almost that of a mulatto, a long and narrow skull, a high forehead, retroussé nose, thick lips, and receding chin. I have found these two ethnical types well distinguished by Dr. Collilmon in the two Caliphates of Matmata. The first seemed to me to predominate at Hadeje; the second prevailing at Matmata Bled Kebira.

Besides these there were seen here and there in the mountains, persons without doubt of Zanatian origin, who recall our Kabyles; a few half-breed Arabs, and also a small number of negroes, more or less Berber in type, exercising in general the important profession of water-carriers, but transforming themselves in an obliging manner into musicians for local fetes.

The Matmatians are at the same time shepherds and husbandmen. They raise herds, of which goats and sheep predominate. The wool of these animals they take to the coast to sell, sometimes raw and sometimes woven. They cultivate barley and wheat, the date, olive, and fig, the products of which transported to Gabes enable them to acquire, by exchange, a quantity of foreign objects which more and more take the place of the articles which they formerly fabricated for themselves. I found in the house of Ali porcelains of Limoges, ordinary glassware,

a tin lantern of Parisian manufacture, copper candlesticks, wax candles, white sugar, a bottle of ink from Dijon, a pair of spectacles with silver rims, knives from Chatellerault, knives and forks of *ruolz*, etc. Nothing of home manufacture remained in the surroundings of the good old man excepting the grey wool of the burnous, the rug from Oudref spread in our room, and the large dishes in basketwork and wood on which the abundant *diffa* was served to us.

This is the case at Hadeje, as well as everywhere else.

All that has not succumbed to European influence is distinctly Arab. Food, clothing, ornaments, arms, etc., suggest in appearance those of the nomads of the neighboring desert.

Their social condition is very similar to that of the Arabs, whom the Matmatians imitate as closely as possible so long as it entails nothing contrary to their traditional legislation (Kanoun). They possess a Zaonia, who enjoys a great reputation in the mountains, and their religious rites follow closely those of the dissenting Ibbadites, whose beliefs they share. They bury their dead, according to Arabian custom, in shallow graves, so near the surface of the earth that a poet, in visiting the spot, has been able to say without exaggeration that in this strange land the dead occupy the place of the living, while the living "have for habitation true sepulchers." "When you see them come forth," the Arab poet goes on to say, "it seems as if they were rising for the day of judgment."

Beni-Zelten and Toujane mark the extreme eastern limit of the country of the Troglodytes. The Berber language is again heard when beyond the last inhabited cave the terraces of the dreary, gray houses of the Zanaitia re-appear, overlooking in the distance the steep cliff, the extended plain, and the sea.

## SUMMARY OF PROGRESS IN ANTHROPOLOGY IN 1891.

By Otis T. Mason.

The purpose of this summary is to draw attention to combined and organized resources, rather than to individual effort. The number of books, pamphlets, papers, etc., read before societies and general meetings and congresses, and of articles in current periodicals, is so great that it were impossible to enumerate them. Furthermore, this is not necessary now as formerly, since several of the organs of anthropological societies publish great lists, and special journals in each division of the subject pay great attention to bibliography. To American readers, particularly to those who desire to commence a course of anthropological studies, the following should be accessible:

*The American Anthropologist*, Washington; *Archiv für Anthropologie*, Braunschweig; *Archivio per l' Antropologia*, Firenze; *Bulletins de la Société d'Anthropologie de Paris; Internationales Archiv für Ethnographie*, Leyden; *Journal of the Anthropological Institute of Great Britain and Ireland*, London; *L'Anthropologie*, Paris; *Mittheilungen der Anthropologischen Gesellschaft in Wien; Revue Mensuelle de l'École d'Anthropologie*, Paris; *Verhandlungen der Berliner Gesellschaft für Anthropologie, etc.*, Berlin; *Zeitschrift für Ethnologie*, by the same society.

Journals of popular character which can not be neglected are: *Academy*, London; *The American Naturalist*, New York; *Athenæum*, London; *Ausland*, Stuttgart; *Nature*, London; *Popular Science Monthly*, New York; *Revue Scientifique*, Paris; *Science*, New York.

The address of Prof. Max Müller, as vice-president of the section of anthropology in the British Association, at the meeting held in Cardiff in August of this year, was a review of the forty years during which he had taken part in this organization. In that early day there was no section of anthropology, the study of mankind being relegated to section D (*zoölogy* and *botany*). In 1851 section E (*geography* and *ethnology*) was formed, the former, however, more and more absorbing the latter until 1884, when section H (*anthropology*) was organized. In 1847 the debates on ethnology were most popular, shared in by Müller, Prichard, Latham, Crawford, Bunsen, Karl Meyer, Prince Lucien Bonaparte, and patronized by Prince Albert. In Prof. Müller's address, the prophecies

of his first meeting are delightfully referred to in connection with their fulfillment of to-day.

The following communications were made before the section of anthropology in 1891:

Social and religious ideas of the Chinese. By R. K. Douglas.
Analysis of vowel sounds. R. J. Lloyd.
Family life of the Haidas. Charles Harrison.
Report of the northwestern tribes of Canada. By the Committee.
On the work of Maj. J. W. Powell. Max Müller.
Ancient language of the natives of Teneriffe. By the Marquess of Bute.
The limits of savage religion. F. B. Tylor.
Couvade. H. Ling Roth.
Customs of the natives of Assam. S. E. Peal.
Burial customs of New Britain. B. Danks.
Barbaric elements in ancient Greece and Italy. G. Hartwell Jones.
The Morocco Berbers. J. E. B. Meakin.
On the worship of the meteorites. H. A. Newton.
Ancient Welsh customs, etc. Dr. Phené.
First sea wanderings of the English race. W. M. Adams.
Old-World myths and the Navajo "Mountain Chant." A. W. Buckland.
East Central African customs. By J. Macdonald.
Report of the prehistoric inhabitants committee.
Report of the Elbolton cave committee.
Instinctive criminality. By S. A. K. Strahan.
The anthropometric method of identifying criminals. By J. G. Garson.
Recent Hittite discoveries. By Dr. Phené.
The Similkameen Indians of British Columbia. By Mrs. S. S. Allison.
Nicobar pottery. By E. H. Man.
Report of the anthropometric laboratory committee.
Report of the anthropological notes and queries committee.
Report of the Indian Committee.

The French Association for the Advancement of Science held its twentieth session in Marseilles, September 17–24. In the eleventh section, devoted to anthropology, the following papers of general interest were read:

M. Fauvelle: Succession of environments inhabited by the series of man's ancestors.
Delisle: Artificial deformation of the skull in France. The coiffures which produce them and the chart of their distribution.
Philippe Rey: The skulls of the insane.
Ernest Chantre: Peoples of Russian Armenia.
Ernest Chantre: Ethnographic objects from the Kurds of Mount Ararat.
M. Layard: Obsidian from Teneriffe.
G. de Mortillet: The paleolithic epochs in their relation to the Alpine glaciers.
F. Barthelemy: Glacial deposits and diluvial deposits of the Mosilla.
Gustave Chauvet: Classification of Quaternary times in Chauvant.
A. de Mortillet: The value of objects of human industry as an element in classifying quaternary deposits.
M. Tardy: Prehistoric religious monuments.
M. Pallery: The hand in Jewish and Mussulman traditions.

A novel feature of this meeting was the choice of a subject for special discussion at the meeting to be held at Pau in 1892 under the presidency of Dr. Magitot, namely, the criminal type from the anthropological point of view.

The Paris school of Anthropology not only continued its course of lectures, but provided for their widespread influence and perpetuation by establishing a monthly journal, *Revue Mensuelle de l'Anthropologie de Paris*. The course of lectures during the year included the following:

G. de Mortillet: The origin of agriculture.
André Lefevre: Linguistic evolution; origin of articulate language.
G. Hervé: General natural history of man and of the human races.
J. V. Laborde: The instinctive and the intellectual functions.
Mahoudeau: Histology of the skin, its attachments and the organs of sense.
Bordier: Acclimation. Role of the interior environment in the phenomena of acclimation.
Manouvrier: Human anatomy and its relations with psychology.
Letourneau: Mythologic evolution among the human races.
A. de Mortillet: Industry among prehistoric peoples and among modern savages.

The Ninth International Congress of Americanists was announced to meet in the Convent of Santa Maria de la Rabida, in the province of Huelva, Spain, from the 7th to the 11th of October, 1892, at the close of the session of the Congress of Orientalists, to be held in Seville October 1 to 6. To celebrate the fourth centennial after the discovery of America, extraordinary preparations were made. The naming of the continent, the voyages of Columbus, the government of the Indians by the different countries interested, and the influence of Europeans upon the aboriginal habits and governments and kindred topics were to be made prominent. The archæologic, ethnographic, linguistic, and historic papers and debates were selected and ordered with reference to the one absorbing event of the year.

The American Association for the Advancement of Science met in Washington under the patronage of a joint committee of all the scientific societies. The Anthropological Society of Washington and the Women's Anthropological Society were especially active in giving success to their section. Papers germane to the study of man were not confined to Section H. The presidential address upon the possibilities of the vegetable kingdom for yielding new plants to the service of man was practically an anthropological paper. The geological section also listened to papers on the quaternary that can not fail to be instructive to students of the antiquity of man. Section I, devoted to economics and social problems, divided the time of many anthropologists with Section H. Prof. Jastrow presided over Section H, and chose as his theme "Analogy as a basis of argument among lower races and among the Folk." Suggestions were made relative to the formation of a section of psychology in the association, but it was thought that more would be lost than gained by diverting attention from the general section of anthropology. The Washington meeting was especially favored by the bringing out of Maj. Powell's Linguistic Map of North America, by papers of Mr. Frank Cushing, and by a minute recital of the ghost dance by Mr. James Mooney, who had been participating therein for

several weeks. The splendid collections of the National Museum and of the Army Medical Museum were thrown open, visits were made to the Piney Branch bowlder quarries and to other aboriginal remains in the vicinity of the capital.

The following papers were read before Section H of the American Association for the Advancement of Science:

The essentials of a good education. W. H. Seaman.
Kava-drinking among the Papuans and Polynesians. Walter Hough.
A linguistic map of North America. J. W. Powell.
Jade implements from Mexico and Central America. Thomas Wilson.
Gold ornaments in the United States National Museum from the United States of Colombia. Thomas Wilson.
Siouan onomatopes interjection and phonetic types. J. O. Dorsey.
On a collection of stone pipes from Vermont. G. H. Perkins.
An experiment in human stirpiculture. Anita Newcomb McGee.
Relics of ancient Mexican civilization. Zelia Nuttall.
Bow-stretchers. Edward S. Morse.
Prehistoric bows. Edward S. Morse.
The Nez Perce country. Alice C. Fletcher.
Relation of a Loveland, Ohio, implement-bearing terrace to the moraines of the ice sheet. Frank Leverett.
Utility of physical study of child life. Laura Osborne Talbott.
Origin of the name "Chautauqua." Albert Gatschet.
Outlines of Zuni creation and migration myths considered in their relation to the Ka-ka and other dramas or so-called dances. Frank Hamilton Cushing.
An ancient human cranium from southern Mexico. F. W. Putnam.
The length of a generation. C. M. Woodward.
Burial customs of the Hurons. Charles A. Hirschfelder.
The Messiah religion and the ghost dance. James Mooney.
Study of a dwarf. Frank Baker.
Stone drills and perforations in stone from the Susquehanna River. Atreus Wanner.
Evidence of the high antiquity of man in America. Thomas Wilson.
On bone, copper, and slate implements found in Vermont. G. H. Perkins.
Some archæological contraventions. Gerard Fowke.
On the distribution of stone implements in the tidewater provinces. W. H. Holmes.
Aboriginal novaculite quarries in Arkansas. W. H. Holmes.
Games of Teton children. J. Owen Dorsey.
Geographical arrangement of prehistoric objects in the United States National Museum. Thomas Wilson.
Curious forms of chipped stone implements found in Italy, Honduras, and the United States. Thomas Wilson.
Inventions of antiquity. Thomas Wilson.
Study of automatic motion. Joseph Jastrow.
Race survivals and race mixture in Great Britain. W. H. Babcock.

The Smithsonian Institution issued two annual reports in 1891, besides separate papers in the proceedings of the United States National Museum. The Bureau of Ethnology published its *Seventh Annual Report*, 1885–'86; Catalogue of Prehistoric Works East of the Rocky Mountains, by Cyrus Thomas; Omaha and Ponka Letters, by J. Owen Dorsey; Bibliography of the Algonquian Language, by J. C. Pilling; The Klamath Indians of Southwestern Oregon (*Cont. to N. A. Ethnol.*, vol. II), by A. S. Gatschet; The Dhegiha Language (*Cont. to N. A. Ethnol.*, vol.

VI), by J. Owen Dorsey; A Dakota-English Dictionary (*Cont. to N. A. Ethnol.*, vol. VII), by Stephen R. Riggs.

The rapid popularization of anthropological knowledge of the best sort is seen in the Contemporary Science Series, edited by Havelock Ellis and published by Walter Scott, London. The volumes already advertised are:

1. The evolution of sex. By P. Geddes and J. A. Thomson.
2. Electricity in modern life. By de Tunzelman.
3. The origin of the Aryans. By Isaac Taylor.
4. Physiognomy and expression. By P. Mantegazza.
5. Evolution and disease. By J. B. Sutton.
6. The village community. By G. L. Gomme.
7. The criminal. By Havelock Ellis.
8. Sanity and insanity. By Charles Mercier.
9. Hypnotism. By Albert Moll.
10. Manual training. By C. M. Woodward.
11. The science of fairy tales. By E. S. Hartland.
12. Primitive folk. By Elie Reclus.
13. The evolution of marriage. By M. Letourneau.
14. Bacteria and their products. By G. S. Woodhead.
15. Education and heredity. By J. M. Guyau.
16. The man of genius. By Cesare Lombroso.

For the purpose of perfecting organization and bringing together the various associations in our country devoted to anthropology, the American Oriental Society appointed a committee to learn if it were practicable to open negotiations with other philological, archæological, and ethnological societies with a view to adopting a common time and place for meeting every other year. The following associations are included in the list:

The American Oriental Society, 1842.
The American Philological Association, 1869.
The Archæological Institute of America, 1879.
The Anthropological Society of Washington, 1879.
The Society of Biblical Literature and Exegesis, 1880.
The Modern Language Association of America, 1883.
The American Folk-Lore Society, 1888.
The American Dialect Society, 1889.

The friends of the natural history of man will look forward with great interest to the result of this inquiry.

In May, 1890, at the request of several gentlemen in Chicago, Prof. F. W. Putnam outlined a plan for an ethnological and archæological exhibit, particularly relating to America, as a desirable and instructive section of the World's Columbian Exposition, this exhibit to be brought together largely by special exploration and research and with the understanding that it should form the nucleus of a permanent ethnological museum in Chicago. This plan was printed in the Chicago Tribune of May 31, 1890.

In the following September, Prof. Putnam was invited to address the Committee on Permanent Organization of the National Board of Com-

missioners on the subject of an ethnological and archæological exhibit, and soon afterwards the Board of Directors invited him to present his views before that body. The substance of these remarks was printed by the Committee on Organization of National Commissioners as an appendix to their report on September 15, 1890.

In January, 1891, the Director-General of the Exposition invited Prof. Putnam to a conference on the scope and plan for Department M, which had been designated by the National Commissioners with the title "Ethnology, Archæology, Progress of Labor and Invention," and on February 5 Prof. Putnam was officially appointed Chief of the Department.

The National Board of Commissioners and the Board of Directors are specially interested in the development of this department, which is so entirely removed from the material interests of the World's Fair. The understanding is that from this exhibit there shall result a permanent Columbus Museum (for all departments of Natural History) of a character worthy of the Exposition and of Chicago. This result will be appreciated by scientists, who will hail with delight the formation of a great museum in this central part of our country.

In former summaries attention has been called to the excellent anthropological work done in Salem, Cambridge, Worcester, New York, Cleveland, Philadelphia, Washington, Cincinnati, St. Louis, Davenport, and other cities; but these by no means include all the organized effort to preserve in our country the history and natural history of man. In almost every American city of importance these are banded together in societies, many of them incorporated, men and women devoted to some branch of anthropology. Omitting the medical societies that publish somewhat, sufficiently catalogued in the *Index Medicus*, the writer has sought to enumerate the organizations in the different States that are equipped for anthropological work. The list has been made long intentionally, quite as much to awaken an interest in the study of archæology and ethnology as to put on record their existence and the amount of good already accomplished by them. Many subscription journals in our country also lend their pages to anthropological papers, and these also find a place in the list in recognition of their services. There are few persons who will not be surprised at the great numbers of media of communication. The work of the future will be to gather them into an organization.

Alabama Historical Society, Tuscaloosa. Publish Alabama Historical Reporter.
Alaska Historical Society, Sitka.
Alaskan Society of Natural History and Ethnology, Sitka.
Albany Institute, New York. Publish transactions.
American Academy of Arts and Sciences, Boston, Mass. Publish proceedings.
American Academy of Political and Social Science, Philadelphia, Pa. Publish the annals of the American Academy of Political and Social Science.
American Anthropologist, Anthropological Society, Washington, D. C.
American Archæological Association, Bennings, D. C.

Anthropological Society, Washington, D. C., publish American Anthropologist.
American Anthropometric Society, Philadelphia, Dr. William Pepper.
American Antiquarian and Oriental Journal, illustrated, Chicago, Ill.
American Antiquarian Society, Worcester, Mass. Publish Archæologia Americana.
American Association for the Advancement of Science, Salem, Mass. Publish proceedings.
American Catalogue (The), New York, office of Publishers' Weekly.
American Catholic Historical Researches, Philadelphia. Publish Quarterly Magazine.
American Dental Association.
American Economic Association, Baltimore, Md. Publications, contributions.
American Folk-Lore Society, Boston, Mass. Publish Journal of American Folk-Lore (quarterly).
American Geographical Society, New York city. Publish bulletin.
American Historical Association, Washington, D. C.
American Institute of Christian Philosophy, Philadelphia.
American Institute of Sacred Literature, New Haven.
American Journal of Archæology and History of Fine Arts.
American Journal of Philology.
American Journal of Psychology (The), Clark University, Worcester, Mass. Quarterly.
American Journal of Science, New Haven.
American Library Association, New York.
American Museum of Natural History, New York city. Publish bulletin.
American Naturalist, Philadelphia.
American Numismatic and Archæological Society, New York city. Publish proceedings.
American Oriental Society, Cambridge, Mass. Publish journal.
American Philological Association, Bryn Mawr, Pa. Transactions.
American Philosophical Society, Philadelphia, Pa. Publish proceedings, transactions.
American School of Classical Studies in Athens, under patronage of the Archæological Institute of America.
American Social Science Association, Concord, Mass. Journal of Social Science.
American Society for Psychical Research. Publish proceedings.
American Society for the Extension of University Teaching, 1502 Chestnut street, Philadelphia.
American Society of Church History, New York. Papers.
American Statistical Association, Boston, Mass. Publish publications.
Annual Report of the American Historical Association.
Annual Report of the Curator of the Museum of American Archæology, in connection with the University of Pennsylvania, University Archæological Association, Philadelphia, Pa.
Annual Report of the Peabody Museum of American Archæology and Ethnology, Cambridge, Mass.
Archæological and Ethnological Papers of the Peabody Museum, Cambridge, Mass.
Archæological Institute of America, Boston, Mass. Annual Report.
Arena (The), Boston, Mass.
Athénée Louisianais (L'), New Orleans, La.
Arkansas Historical Society, Little Rock, Ark.
Boston Scientific Society, Boston, Mass.
Boston Medico-Psychological Society, Worcester, Mass. American Journal of Psychology.
Boston Society for Ethical Culture, Dorchester, Mass.
Boston Society of Natural History, Boston, Mass. Guides for Science Teaching.

Brooklyn Ethical Association.

Brooklyn Institute, Brooklyn, N. Y.

Bulletins of Proceedings. Year Book.

Brookville Society Natural History, Brookville, Ind. Bulletin.

Buffalo Historical Society, Buffalo, N. Y. Annual Report and Proceedings; Transactions.

Buffalo Society of Natural Sciences, Buffalo, N. Y. Bulletin.

California Academy of Sciences, San Francisco, Cal. Bulletin; Memoirs; Proceedings; Occasional Papers.

California Historical Society, San Francisco, Cal. Collections.

Canadian Record of Science, Montreal, Canada.

Cayuga County Historical Society, Auburn, N. Y. Collections.

Central Ohio Scientific Association, Urbana, Ohio. Proceedings.

Century Magazine, New York.

Chautauqua Literary and Scientific Circle, Buffalo, N.Y. Chautauquan, The.

Cincinnati Museum Association. Art Academy of Cincinnati.

Cincinnati Society of Natural History, Cincinnati, Ohio.

Clark University, Worcester, Mass. Psycho-physical laboratory.

Colorado Scientific Society, Denver, Colo. Proceedings.

Colorado, State Historical and Natural History Society of, Denver, Colo. Nothing yet published.

Connecticut Academy of Arts and Sciences, New Haven, Conn. Transactions.

Davenport Academy of Natural Sciences, Davenport, Iowa. Proceedings.

Delaware Historical Society, Wilmington, Del.

Denison Scientific Association, Denison. Texas. Memoirs.

Des Moines Academy of Science, Des Moines, Iowa. Bulletin.

Elisha Mitchell Scientific Society, Chapel Hill, N. C. Journal.

Elliot Society of Science and Art, Charleston, S. C. Proceedings.

Essex Institute, Salem, Mass. Bulletin; Historical Collections.

Evolutionist, The, Boston, Mass.

Fairfield County Historical Society, Bridgeport, Conn.

Florida Historical Society, St. Augustine, Fla.

Franklin Institute, Philadelphia, Pa. Journal.

Friends' Historical Association, Philadelphia, Pa.

Fulton County Scientific Society, Avon, Ill.

Geographical Society of the Pacific, San Francisco, Cal. Kosmos (the official organ of). Transactions; Proceedings.

Georgia Historical Society, Savannah, Ga. Collections.

Gorges Society, Portland, Me. Publications.

Hawaiian Historical Society.

Harvard College, Cambridge, Mass. Quarterly Journal of Economics.

Hemenway Southwestern Archæological Expedition. A journal of American Ethnology and Archæology. Boston, Vol. I, 1889.

Historical Society of Nashville, Tenn.

Huguenot Society of America, New York City. Collections; Proceedings.

Illinois State Historical Society, Springfield, Ill. Practically only a library.

Index Catalogue of the Library of the Surgeon-General's Office, Washington, D. C.

Index Medicus, Washington, D. C.

Indian Rights Association, Philadelphia, Pa.

Iowa Academy of Sciences, Des Moines, Iowa. Proceedings.

Iowa State Historical Society, Des Moines, Iowa. Iowa Historical Record.

Jefferson County Historical Society, Watertown, N. Y.

Johns Hopkins University, Baltimore, Md. Universal History and Political Science studies; social Science, Education and Government, American Journal of Philology; Studies from Biological Laboratory.

Journal (A) of American Ethnology and Archæology, Boston and New York.
Journal (The) of American Folk-Lore, Boston and New York. Quarterly.
Journal of the Military Service Institution, New York.
Kansas Academy of Science, Topeka, Kans. Transactions.
Kansas State Historical Society, Topeka, Kans. Transactions.
Lackawanna Institute of History and Science (?), Pa. Proceedings and Collections.
Lexington Historical Society, Lexington, Mass. Proceedings.
Linnæan Society of New York, New York City. Transactions; Abstract of Proceedings.
Long Island Historical Society, Brooklyn, N. Y. Memoirs.
Louisiana Historical Society, Baton Rouge, La.
Lowell Institute, Boston, Mass. Courses of lectures.
Magazine of American History. Quarterly.
Maine Historical Society, Portland, Me. Collections; Proceedings and Collections, new series; Documentary History of Maine.
Malcaster College, St. Paul, Minn. Contributions.
Maryland Academy of Sciences, Baltimore, Md. Transactions.
Maryland Historical Society, Baltimore, Md. Annual Report.
Massachusetts Historical Society, Boston, Mass. Collections; Reports.
Meriden Scientific Association, Meriden, Conn. Transactions.
Metropolitan Museum of Art, Central Park, New York.
Michigan Pioneer and Historical Society, Lansing, Mich. Pioneer Collections; Historical Collections.
Middlebury Historical Society, Middlebury, Vt. Papers and Proceedings.
Minnesota Academy of Natural Sciences, Minneapolis, Minn. Bulletins.
Minnesota Historical Society, St. Paul, Minn. Collections; History of Ojibwa Nation; Biennial Reports.
Mississippi Historical Society, Jackson, Miss.
Missouri Historical Society, St. Louis, Mo. Publications.
Modern Language Association of America, Baltimore, Md. Transactions; Transactions and Proceedings; Proceedings; Publications.
Monist (The), Chicago, Ill. Quarterly Magazine.
National Academy of Sciences, Washington, D. C. Annual Reports; Memoirs.
National Educational Association, Washington, D. C. Proceedings.
National Geographical Society, Washington, D. C. National Geographical Magazine.
National Prison Association. Reports.
Natural History Society of Carbondale, Ill.
Nature's Realm, New York. A monthly magazine.
Nebraska State Historical Society, Lincoln, Neb. Report of Secretary Biennial: Transactions and Reports.
Newburgh Bay, Historical Society of, Newburgh, N. Y.
New England Historical and Genealogical Register, Boston, Mass.
New Hampshire Antiquarian Society, Hopkinton, N. H.
New Hampshire Historical Society, Concord, N. H. Collections; Proceedings.
New Haven Colony Historical Society, New Haven, Conn. Papers.
New Jersey Historical Society, Newark, N. J. Proceedings; Documents relating to the colonial history of New Jersey; Journal of the Governors and Council of New Jersey.
New Jersey Natural History Society, Trenton, N. J. Journal.
New London County Historical Society, New London, Conn. Records and Papers.
New Mexico, Historical Society of, Santa Fe, N. Mex.
New Orleans Academy of Sciences, New Orleans, La. Papers.
Newport Historical Society, Newport, R. I. Reports.
Newport Natural History Society, Newport, R. I. Proceedings.

Newton Natural History Society, Newtonville, Mass. Bulletin.

New York Historical Society, New York City. Collections.

New York Academy of Anthropology, New York City. Transactions; Miscellaneous Papers.

New York Academy of Sciences, New York City. Annals; Transactions.

New York State Museum of Natural History, Albany, N. Y. Bulletin.

North Carolina Historical Society, Chapel Hill, N. C.

Numismatic and Antiquarian Society of Philadelphia. Report of Proceedings.

Ohio Archæological and Historical Society, Columbus, Ohio. Publications, quarterly.

Ohio Historical and Philosophical Society of Cincinnati, Ohio. Annual reports; Publications.

Old Colony Historical Society, Taunton, Mass. Collections; Proceedings.

Oneida Historical Society, Utica, N. Y. Open Court (The), weekly, Chicago.

Oriental Club, Philadelphia. Pennsylvania University.

Overland Monthly, San Francisco.

Peabody Museum of American Archæology and Ethnology. Annual report.

Peabody Academy of Science, Salem, Mass. Publications; Memoirs.

Pedagogic (The) Seminary, Clark University, Worcester, Mass., G. Stanley Hall.

Pennsylvania (The) Magazine, Philadelphia, Pa. Quarterly.

Pennsylvania Historical Society of Philadelphia, Pa. Pennsylvania Magazine of History and Biography, quarterly.

Pennsylvania Historical Society of Pittsburg and Western Pennsylvania, Pittsburg, Pa.

Philadelphia Academy of Natural Sciences, Philadelphia, Pa. Journal; Proceedings; monthly.

Philadelphia Social Science Association, Philadelphia, Pa. (now merged into Academy of Political and Social Economy of America).

Pejepscot Historical Society, Brunswick, Me. Collections.

Political Science Quarterly (The), New York.

Popular Science Monthly (The), New York.

Proceedings of the Academy of Natural Sciences of Philadelphia.

Proceedings of the American Antiquarian Society, Worcester, Mass.

Proceedings of the American Association for the Advancement of Science.

Proceedings of the Canadian Institute, Toronto, Canada.

Quarterly Bibliography of Anthropologic Literature, American Anthropologist, Washington, in every number.

Quarterly Journal of Economics, Harvard University, Cambridge, Mass.

Rhode Island Historical Society, Providence, R. I. Proceedings; collections.

Rochester Academy of Science, Rochester, N. Y. Proceedings.

Santa Barbara Society of Natural History, Santa Barbara, Cal.

School of Applied Ethics, Plymouth, Mass.

Scientific American, with Supplement, New York, weekly.

Semitic Department, Harvard University. Programme separate.

Seventh report of committee appointed to investigate the physical characters, languages, and industrial and social condition of the Northwestern tribes of the Dominion of Canada. Report British Association for Advancement of Science, 1891, V. III.

Smithsonian Institution, Washington, D. C.

Society for Political Education, New York City. Economic Tracts.

South Carolina Historical Society, Charleston, S. C. Collections.

Southern California, Historical Society of, Los Angeles, Cal. Constitution; Warm and Cold Ages; Annual Publications.

Southern Historical Society, Richmond, Va. Papers.

South Nantick, Historical, Natural History, and Library Society of, Massachusetts. A review of the first fourteen years of the.

Staten Island, Natural Science Association of New Brighton, N. Y. Proceedings.
St. Louis, Academy of Science of Missouri. Transactions.
St. Paul Academy of Science, St. Paul, Minn.
Tacoma Academy of Sciences, Tacoma, Washington, D. C.
Tennessee Historical Society, Nashville, Tenn.
Tennessee Historical Society Papers. Proceedings of the, at Murfreesboro.
Texas State Historical Society, Texas.
Texas Academy of Science, Dr. Everhart, president.
Transactions of the Canadian Institute, Toronto.
Transactions of the Psychological Society of Moscow.
Union Ethical Society, Philadelphia, Pa. The Ethical Record (ten numbers only) succeeded by the International Journal of Ethics.
United States National Museum, Washington, D. C. Bulletins.
University Archæological Association of the University of Pennsylvania, in Philadelphia. Designed to co-operate with the department of archæology and paleontology.
University of Michigan, Ann Arbor, Mich. Philosophical Papers.
University of Nebraska, Lincoln, Neb.
University Studies. Department of History and Economics. Seminary papers.
University of Pennsylvania. Philadelphia, Pa.
Virginia Historical Society, Richmond, Va. Virginia historical collections.
West American Scientist. A popular monthly review and record for the Pacific Coast.
Western Reserve and Northern Ohio Historical Society, Cleveland, Ohio. Report twenty-fourth annual meeting.
Weymouth Historical Society, Weymouth, Mass. Publications.
Wisconsin Academy of Sciences, Arts, and Letters, Madison, Wis. Transactions.
Wisconsin Naturalist, Madison, Wis. Monthly.
Wisconsin, Natural History Society of, Milwaukee, Wis. Proceedings; occasional papers.

The anthropological museum is an essential part of the natural history of man. The true motive and spirit of a useful museum are well set forth in Dr. Goode's lecture on the museums of the future. The ideas enforced therein connect exhibition with study and instruction, and make it plain that the founders of such an organization should provide for indefinite expansion. The dearth of enterprise and enthusiasm upon this interesting field has been in the past a cause of lament.

In the University of Pennsylvania the museum of archæology is in successful operation, and since 1889 a "University Archæological Association" has grown to have a contributing membership of 275. The president of the university is also presiding officer of the association, and there is the closest sympathy between this organization and the department of archæology and palæontology in the University.

A department of archæology and palæontology in the University, with American, Babylonian, Egyptian, and Oriental sections in the Museum of Archæology and Palæontology, has been organized with Mr. Stewart Culin as secretary.

The following proposed classification and international nomenclature of the anthropologic sciences has been offered by Dr. D. G. Brinton:

ANTHROPOLOGY.

I. *Somatology.*—Physical and experimental anthropology.
II. *Ethnology.*—Historic and analytic anthropology.
III. *Ethnography.*—Geographic and descriptive anthropology.
IV. *Archæology.*—Prehistoric and reconstructive anthropology.

I. *Somatology.*—1. Internal somatology: Osteology, craniology, prosopology, myology, splanchnology. 2. External somatology: Anthropometry, color, hair, canons of proportion, physical beauty. 3. Psychology: Experimental and practical, sensation, rates of nervous impulse, brain and nerve action. 4. Developmental and comparative somatology: Embryology, heredity, teratology, human biology, evolution, anatomy of anthropoids, ethnic anatomy and physiology, comparative nosology and medical geography, fertility and sterility, racial pathology, criminal anthropology, vital statistics, anatomical classification of races.

II. *Ethnology.*—1. Sociology: Systems of government and the social contract, laws and ethical standards, the marriage relation and rules of consanguinity and descent, social classes and institutions, international relations (war, commerce, colonization). 2. Technology: The utilitarian arts, as tool-making, ceramics, architecture, agriculture, means of transportation, clothing, weights and measures, media of exchange; the æsthetic arts—music, drawing, painting, sculpture, decoration, games, cookery, perfumery. 3. Religion: Psychological origin and development; personal, family, tribal, and world religions; animism, fetichism, polytheism, monotheism, atheism; mythology and mythogeny; symbolism and religious art; sacred places and objects; rites, ceremonies, and mortuary customs; religious teachers, classes, and doctrines; theocracies; analyses of special religions; philosophy and natural history of religions. 4. Linguistics: Gesture and sign language; spoken language—parts of speech, logic of grammar, origin, growth, and classification of languages, relation to ethnography; written language—pictographic, symbolic, ideographic, and phonetic writing, evolution of alphabets, phonetic systems; forms of expression—poetic (metrical, rhythmical), dramatic, prosaic. 5. Folk-lore: Traditional customs and narratives, folk-sayings, superstitious beliefs and practices.

III. *Ethnography.*—1. General ethnography: Origin, characteristics, and subdivisions of races and peoples; the "geographical provinces" or "areas of characterization;" anthropo-geography; lines of migrations and national intercourse. 2. Special ethnography: The Eurafrican or White Race (North Mediterranean and South Mediterranean branches), the Austafrican or Black Race, the Asian Race (Sinitic and Sibiric branches), the American Race, Insular and Littoral peoples (Nigritic, Malayic, and Australic stocks).

IV. *Archæology.*—1. General archæology: Geology of the epoch of man; glacial phenomena; diluvial and alluvial deposits; physical geography of the quaternary; prehistoric botany and zoölogy; prehistoric ages—the age of stone (palæolithic period, neolithic period), the age of bronze, the age of iron, prehistoric commerce, palethnology; proto-historic epoch. 2. Special archæology: Egyptian, Assyrian, Phenician, Classical, Medieval, and American Archæology.

## BIOLOGY.

On the biological side the best comprehensive survey of anthropology is Topinard's "L'Homme dans la Nature." It will be remembered that in 1876 the author published his "Anthropologie," an elementary treatise inspired and patronized by Broca. In 1886 appeared the author's "Elements d'Anthropologie Generale," an elaborate volume of over eleven hundred pages, of which the present work is a comprehensive abridgement, bringing the subject down to date. The lectures in the Ecole d'Anthropologie, based on studies made upon materials gathered in the museum of the Societe d'Anthropologie, the Musee Broca, of the Ecole, and in other collections of Paris, continue to be the best effort to make public the results of biological anthropology. In our own country, outside the medical colleges and the Surgeon General's laboratory, little anthropo-biological work was done; an exception is to be made in the matter of psycho-physics. If one should wish however to become acquainted with the biological work of the world, he would only have to turn to the *Index Medicus* and the *Index Catalogue* of the Surgeon General's library. The purely anthropological part of these catalogues also appears in the current numbers of *American Anthropologist*, edited by Dr. Robert Fletcher.

*Psycho-physics.*—For the study of psysho-physics and kindred branches of anthropology the *American Journal of Psychology* is the standard authority. The current literature of the world is there reviewed, and the titles of foreign periodicals and journals contributing to the science are given.

In March, Dr. Henry H. Donaldson delivered before the Boston Medico-Psychological Society a course of six lectures on cerebral localization. This series draws attention to a doubly interesting fact, namely, the existence of a medico psychological society, coupled with a course of public lectures for pedagogical purposes. The subjects of the lectures were as follows:

(1) Recent advances in our knowledge concerning the structure of nerve cells and nerve fibers, and the relation of these to one another. The most valuable anthropometric publication of the year is Risley's "Tribes and Castes of India," two octavo volumes, containing 876 pages of measurements, to be followed by a volume which will give full analyses of the data, indicating their bearing upon the ethnology of northern India, and also upon certain more general questions which have been

discussed in Europe. The measurements were taken in Bengal, the Northwestern Provinces, and the Panjab, in 1886–1888. Topinard's measures and instruments were employed, with the exception of the naso-malar index of Oldfield Thomas. (*J. Anthrop. Inst.* May, 1885).

(2) Continuation upon the architecture of the nervous system.

(3) The motor regions of the brain. The middle portions of both hemispheres contain motor centers.

(4) The sensory centers. The motor centers form a dividing line in the cortex, behind which lie the sensory centers, and in front is an unoccupied area which is left out of the discussion.

(5) Cerebral localization in the vertebrate series becoming less perfect as we pass downward.

(6) The principal explanations which have been offered for the phenomena of cerebral localization and some of the points of contact between these phenomena and psychology.

Dr. Donaldson's observations on the brain and several sense-organs of the blind deaf-mute, Laura Dewey Bridgman, in the *American Journal of Psychology* (iv, 248–249) is accompanied with a bibliography of ninety-two titles, bearing upon the study of the brain and sense organs in health and disease. These titles are numbered and references to them in the text are made by the numbers and not by foot notes.

Dr. Edmund C. Sanford presents in the *American Journal of Psychology* (IV, 141–155) the outlines of a course of study of lectures in physiological psychology. This is done not only to encourage the establishment of laboratories, but to assist college men and others, who are not prepared to make original investigations, in repeating the experiments of the best establishments. In each case the apparatus and the method of applying it are minutely described. The following program is followed:

I. *The dermal senses.*—(1) Sensations of contact. (2) Sensations of temperature. (3) Sensations of pressure.

II. *Static* and *kinæsthetic senses.*—(1) Recognition of the posture of the body as a whole. (2) Sensations of rotation. (3) Sensation of progressive motion. (4) Muscle sense. (5) Innervation sense. (6) Sensations of motion. (7.) Sensation of resistance. (8) Bilateral assymmetries of position and motion.

In an elaborate paper on the psychology of time, Mr. Hebert Nichols reviews the terms and expressions for time in the classic authors, follows the conception of a psychological recognition of time historically, and completes his essay with a review of modern psycho-physical experiments in this direction. As a summary of the experiments of Horing, Mach, Vierordt, Kollert, Estel, Mehner, Glass, Stevens, Ejner, and Münsterberg the most conclusive result may thus be summed up.

Nearly all persons, under nearly all conditions, find a particular length of interval more easily and accurately to be judged than any other. This "indifference point," or interval of best judgment, is very variable for different individuals and for different times and conditions.

"The sign of the Constant Error is usually constant in both directions from the Indifference Point."

Where norm and re-production are single, the constant error is *minus* for intervals longer and *plus* for intervals shorter than the indifference interval. "Where norm and re-production are multiples, the constant error is *plus* for intervals longer and *minus* for those shorter than the indifference interval. The majority of evidence is strongly against the validity of Weber's law; also against any fixed or constant periodicity.

"Later investigators look to physiological processes for explanations of time judgments, and particularly to rythmic habits of nerve centers. Whether such processes as breathing, pulse, leg-swing, etc., govern our perceptions or whether the more general rythmic functions of the higher cephalic centers are in themselves the basis of time judgment is now the important question."

In 1890, was founded in Hamburg and Leipzig, *Zeitschrift für Psychologie und Physiologie der Sinnesorgane*, a bi-monthly octavo under the editorship of Hermann Ebbinghaus and Arthur König, assisted by H. Aubert, S. Exner, H. v. Helmholtz, E. Hering, J. v. Kries, Th. Lipps, G. E. Müller, W. Preyer, and C. Stumpf.

Original papers by the most distinguished investigators are published in each number, works of chief importance are reviewed, and, of the greatest value, a bibliography of psycho-physical literature for 1889 is given in the fourth number, pages 365–418. This bibliography is a model of convenience. The titles are classified and numbered and an alphabetical list of authors refers in each case to the title of the author's book. Thus it is possible to exhibit the classification of the material, the full title, and to find the work through three separate lists.

The Society for Psychical Research continued its active investigations upon the phenomena of hypnotism, animal magnetism, suggestive therapeutics, psycho-therapeutics, phantasms of the living, phantasms of the dead, clairvoyance, premonitions, hallucinations, thought-transference or telepathy, and the like. In order to stimulate its friends and members to renewed activity, a circular was issued insisting that "the value to be attached to the evidence already collected must largely depend on its continuous reënforcement by fresh cases of like kind observed with care and recorded without delay. In the second place, supposing that the general facts, say of telepathy or of veridical apparitions, were even universally admitted, it would still be a matter of prime interest and importance to discover as much as possible of the laws which govern these strange phenomena, and it is therefore, impossible to assign any limit to the number and variety of cases which might be collected and registered with this end in view."

The most noticeable advance in the prosecution of this part of anthropological work is in the line of co-ordination and co-operation. The Psychological Society of Moscow was founded in 1888 for the discussion of problems in psychology, its foundation, theory, applications, and

history. The society has published three volumes of transactions. A journal was founded entitled "*Problems in Philosophy and Psychology.*"

A grant was made to the Toronto University for the equipment of a laboratory of experimental psychology. Offers were made to students at once to furnish such apparatus as should be needed for the present purposes, and promises given that the provincial government would print the results of the investigation should these results warrant it.

For the study of psycho-physics and kindred branches of anthropology, the *American Journal of Psychology* is the standard authority. The current literature of the world is there reviewed and the titles of foreign periodicals and journals contributing to the science are given. Outside of this eminent journal the entire literature of the subject is to be sought in the following:

Allgemeine Zeitschrift für Psychiatrie und psychisch-gerichtliche Medicin.
Annales Médico-Psychologiques.
Archives de Neurologie. Charcot, Paris.
Archiv für die gesammte Physiologie. Pflüger.
Archiv für Physiologie. Dubois-Reymond.
Archiv für Psychiatrie und Nerven-Krankheiten.
Brain.
Deutsche Zeitschrift für Nervenheilkunde.
Mind.
Philosophische Studien. Wundt.
Revue de l'Hypnotisme. Bérillon.
Revue Philosophique. Ribot.
Rivista sperimentale di Freniatria e di Medecina Legale.
Zeitschrift für Psychologie und Physiologie der Sinnesorgane. Ebbinghaus.

## ETHNOLOGY.

Two contributions to ethnographic science made in this year should be named together, Powell's Linguistic Map of North America and Brinton's "American Race." The former is the gathered result of all that has been done hitherto in locating North American stocks and tribes, systematized and put into shape by thirteen years of continuous effort of Major Powell and the Bureau of Ethnology. The latter may also be called the result of a life-long inquiry. The ethnography of South America has been in an unsatisfactory condition, and the first thing to do was to sum up carefully previous knowledge. This Dr. Brinton has accomplished, thus paving the way for systematic effort in the future. Below will be found the North American stocks as arranged by Major Powell, followed by a list of stocks as laid down by Dr. Brinton. The two form a continuous series from one end of the continent to the other, the stocks being arranged alphabetically under three titles, North America, Middle America, South America.

### NORTH AMERICAN STOCKS.

Algonquian: Of the North Atlantic seaboard and west through the Northern States, Lake region, and Canada to the Rocky Mountains.

Athapascan: Of the interior of British America; isolated communities on the Columbia River, Oregon, California, Arizona, and New Mexico.

**Attacapan**: Area on Texas coast.

**Beothukan**: Portion of Newfoundland.

**Caddoan**: Of northern Nebraska, western Arkansas, southern Indian Territory, western Louisiana, and northern Texas.

**Chimakuan**: Of part of the southern shore of Puget Sound.

**Chimarikan**: On New and Trinity rivers, Northern California.

**Chimmesyan**. The region of Nasse and Skeena rivers, west coast of British Columbia.

**Chinookan**: Banks of the Columbia River as far up as The Dalles.

**Chitimachan**: About Lake Barataria, southern Louisiana.

**Chumashan**: Coast of California from about the thirty-fourth parallel to a little north of the thirty-fifth.

**Coahuiltecan**: Of southwestern Texas and northeastern Mexico.

**Copehan**: West of the Sacramento as far north as Mount Shasta, California.

**Costanoan**: Coast of California from the Golden Gate south to Monterey Bay.

**Eskimauan**: East and west coasts of Greenland; coast of Labrador as far south as Hamilton Inlet; and the Arctic coast westward, including part of the shore of Hudson Bay, to western Alaska, including the Aleutian Islands.

**Esselenian**: Coast of California from Monterey Bay to Santa Lucia Mountain.

**Iroquoin**: The St. Lawrence River region north of Lake Erie, northern Pennsylvania, State of New York, the lower Susquehanna in Pennsylvania and Maryland, northeastern North Carolina, southwestern West Virginia, western North Carolina, and most of Kentucky and Tennessee.

**Kalapooian**: Valley of the Willamette River, Oregon.

**Karankawan**: Texas coast around Matagorda Bay.

**Keresan**: Upper Rio Grande, and on the Jemez and San José rivers, New Mexico.

**Kiowan**: Upper Arkansas and Purgatory rivers, Colorado.

**Kitunahan**: Cootenay River region, mostly in British Columbia.

**Koluschan**: Northwest coast from 55° to 60° north latitude.

**Kulanapan**: Russian River region, and California coast from Bodega Head north to about latitude 39° 30′.

**Kusan**: Coast of middle Oregon, Coos Bay and River, and at the mouth of Coquille River, Oregon.

**Lutuamian**: Region of Klamath Lakes and Sprague River, Oregon.

**Mariposan**: Interior of California, east of the coast range, and south of Tulare Lake in a narrow strip to below Tulare Lake, north as far as the Fresno River.

**Moquelumnan**: Interior of California, bounded on the north by the Cosumnes River, on the south by the Fresno, on the east by the Sierras, and on the west by the San Joaquin; an area north of San Francisco and San Pablo Bays as far as Bodega Head and the headwaters of the Russian River.

**Muskhogean**: The Gulf States from the Savannah River, and the Atlantic west to the Mississippi, and from the Gulf to the Tennessee River.

**Natchesan**: On St. Catherine Creek, near the site of the present city of Natchez.

**Palaihnihan**: Drainage of Pit River in northeastern California.

**Piman**: On the Gila River, about 160 miles from its mouth, and on the San Pedro in Arizona, and in Mexico on the Gulf of California.

**Pejunan**: California; east bank of the Sacramento, about 100 miles from its mouth, north to Pit River, eastward nearly to the borders of the State.

**Quoratean**: Lower Klamath River, Oregon, from Happy Camp to the junction of the Trinity and Salmon River valley.

**Salinan**: Region around the San Antonio and San Miguel missions, California.

**Salishan**: Northwestern part of Washington, including Puget Sound; eastern Vancouver Island to about midway its length; coast of British Columbia to Bute Inlet; and the region of Bentinck Arm and Dean Inlet.

**Sastean**: Middle Klamath River, northern California.

**Shahaptian**: Upper Columbia River, and its tributaries in northern Oregon and Idaho and southern Washington.

**Shoshonean**: Occupying generally the Great Interior Basin of the United States, as far as the Plains, and reaching the Pacific in Los Angeles, San Bernardino, and San Diego counties, California.

**Siouan**: The Dakotas, parts of Minnesota, Wisconsin, Iowa, Nebraska, Kansas, Missouri, Arkansas, Indian Territory, with isolated colonies in Alabama (Biloxi), the Carolinas (Catawba), and borders of Virginia and North Carolina (Tutelo).

**Skittagetan**: Queen Charlotte Islands, Forester Island, and southeastern part of Prince of Wales Island.

**Takilman**: Oregon coast about the lower Rogue River.

**Tañoan**: Rio Grande and tributary valleys, from about 30° to about 36° 30′.

**Timuquanan**: Florida.

**Tonikan**: Lower Yazoo River, Mississippi.

**Tonkawan**: Western and southwestern parts of Texas.

**Uchean**: Lower Savannah River and perhaps the South Carolina coast.

**Waiilatpuan**: Lower Walla Walla River, Oregon, and about mounts Hood and Jefferson.

**Wakashan**: West coast of Vancouver Island and northwest tip of Washington.

**Washoan**: Eastern base of the Sierras, south of Reno, Nevada, to the lower end of Carson Valley.

**Weitspekan**: Lower Klamath River, Oregon, from the mouth of the Trinity.

**Wishoskan**: Coast of California from just below the mouth of Eel River to a little north of Mad River.

**Yakonan**: Along the lower Yaquina, Alsea, Siuslaw, and Umpqua rivers, Oregon.

**Yanan**: Chiefly in the southern part of Shasta County, California.

**Yukian**: Round Valley, California and west to the coast.

**Yuman**: Lower California; the Colorado from its mouth to Cataract Creek; the Gila and tributaries as far east as the Tonto Basin, Arizona.

**Zuñian**: A small area on Zuñi River, western New Mexico.

MIDDLE AMERICAN STOCKS.

**Aztecan**: Slope of the Pacific coast from about the Rio del Fuerte, in Sinaloa, N. lat 26° to the frontiers of Guatemala, except a portion of the isthmus of Tehuantepec. Dr. Brinton makes this a branch of the Ute-Aztecan stock under the name of Nahualtecan.

**Chapanec**: Chiapas, Mexico.

**Chinantec**: Oaxaca, on the frontiers of the province of Vera Cruz.

**Guatuso**: Upper waters of Rio Trio, Nicaragua.

**Huave**: Isthmus of Tehuantepec, on the Pacific Ocean.

**Lenca**: Central Honduras.

**Matagalpan**: Nicaragua, in and around the department of Matagalpa, Segovia, and Chontales.

**Maya**: Yucatan, Guatemala, and Tabasco.

**Otomi**: States of Queretaro and Guanajuato, Mexico, from the valley of Mexico to the Rio Verde. On the west it adjoined the Tarascas of Michoacan; on the east the Huastecs of Pauuco.

**Rama**: Bluefield Lagoon.

**Subtiaba**: Near the modern city of Leon, in Nicaragua.

**Tarascan**: State of Michoacan, west of the valley of Mexico.

**Tequistlatecan**: Oaxaca, on Pacific coast.

**Totonacan**: Territory of Totonicapan, now in state of Vera Cruz.

**Ulva**: Head waters of streams emptying along the Musquito coast.

**Zapatec-Mixtec**: Oaxaca, Mexico, and adjoining regions.

**Zoque**: Isthmus of Tehuantepec and adjacent portions of Chiapas and Oaxaca.

SOUTH AMERICAN STOCKS.

**Alicaluf**: Terra del Fuego.

**Araua**: On the Jurua, Madeira, and Parus rivers, Brazil.

**Arawak**: Most widely disseminated. From head waters of the Paraguay River, along the highlands of southern Bolivia to the Goajiros Peninsula, and thence to include all the Antilles, both Greater and Lesser.

**Atacamian**: About 20° to 23° south in the vicinity of Atacama, west coast.

**Aucanian**: Both sides of the Andes, in Chili, and on the Pampas.

**Aymara**: Peru and Bolivia, about Lake Titicaca.

**Barbacoa**: Colombia, about 1° and 2° north latitude.

**Betoya**: Foot of the mountains of Bogota, in Orinoco drainage.

**Canichana**: On the river Mamore between 13° and 14°, Bolivian highlands.

**Caraja**: Affluents of the Araguay, province of Goyas, southern Brazil.

**Carib**: Lesser Antilles, Caribby Island, and mainland of South America from mouth of Essequibo River to the Gulf of Maracaibo.

**Catamarena**: Gran Chaco, Catamarca.

**Changuina, or Dorasque tribes**: Isthmus of Panama, on river Puan.

**Charrua**: Gran Chaco plains, stretching from the banks of the Parana to the sea-coast.

**Chibcha**: In both directions from the Isthmus of Panama, specially throughout New Granada (Colombia).

**Chiquito**: Bolivian highlands, between 16° and 18° south.

**Choco**: Isthmus of Panama, eastern shore of the Gulf of Uraba, and much of the lower valley of the Atrato.

**Churoya**: Orinoco basin, above the falls of the Guaviare, and along the Rio Guijar and the Meta.

**Cocanuca**: Southern Colombia.

**Cuna**: Isthmus of Panama from Gulf of Uraba to the river Charres on the west.

**Guaycuru**: Gran Chaco, on the Paraguay and the Pilcomayo rivers.

**Jivaros**: On the mountain slopes of the Cordillera, on the Marañon River, Brazil.

**Kechua**: Spoken by an unbroken chain of tribes for nearly 2,000 miles from 3° north to 32° south on the western border of South America, chiefly in Peru.

**Lama**: On the river Javary, Brazil.

**Lule**: Vermejo and Pilcomayo rivers, Gran Chaco.

**Maina**: Upper Marañon, Brazil, and in the uplands around Cerros de Mamas.

**Mataco**: Vermejo River, Gran Chaco.

**Mocoa**: Columbia, between 1° and 2° north, along Rio de los Engaños or Yari.

**Mosetena**: Bolivian highlands, on the banks of the Mamore and Chavari rivers.

**Ond**: Terra del Fuego.

**Paniquita**: Columbia, north and west of the Chibchas.

**Pand**: Upper Ucayale River, Peru.

**Payagua**: Paraguay River, Gran Chaco.

**Peba**: Javary River, Brazil.

**Puquina**: On the islands and shores of L. Titicaca.

**Samuca**: On the northern border of the Gran Chaco, between 18° and 20° south.

**Tacana**: Bolivian highlands, on the banks of the rivers Mamore and Chavari.

**Timote**: Venezuela, Merida, south of the plains in the interior from Lake Maracaibo.

**Tupi**: Along the seaboard from the mouth of the La Plata to the Amazon and far up the streams of the latter.

**Tapuya**: Most ancient and extensive now living in Brazil. From 5°–20° south, and from the Atlantic to the Xinger River.

**Tzonecan**: Patagonia. The Patagonians call themselves Chonek, or Tzoneca, or Inaken.

**Yahgan**: Tierre del Fuego.

**Yunca**: Peru, near the sea, between 5° and 10° south.

**Yurucari**: Bolivian highlands, on the banks of the Mamore and Chavari.

**Zaparo**: One of the most extended stocks in the upper valley of the Amazon.

The Hemenway Southwestern Archæological and Ethnological expedition began to bear fruit in the publication of a "*Journal of American Ethnology and Archæology*," edited by J. Walter Fewkes, conductor of the expedition. This will be followed by other volumes, putting on permanent record the results of Mrs. Hemenway's liberality during a series of years in sustaining the researches of Cushing and Bandelier, and subsequently of Mr. Fewkes. The first volume relates especially to Zuñi.

An ethnographic contribution not to be ignored is a series of papers by Dr. Ernst, of Caracas, Venezuela, on the aborigines of that republic, published in the *Boletin del Ministerio de Obras Publicas*. In the same journal Dr. G. Marcano contributes a series of papers on the pre-Columbian ethnography of Venezuela.

The publishers of our latest encyclopædias, such as Johnson's, Chambers's, Stanford's, Cassell's, etc., have earned the gratitude of ethnologists by employing men of acknowledged ability to prepare the descriptive articles on tribes and peoples. The geographic societies also have borne a conspicuous part in collecting and preserving data for future compilations regarding ethnology. Especially useful in these studies are the *Journal of the Anthropological Institute* of London, *L'Anthropologie* of Paris, and the *Zeitschrift and Verhandlungen* of the Berlin Anthropological Society.

## LANGUAGE.

In his lecture entitled "Du cri a la parole," delivered in l'Ecole d'Anthropologie de Paris, and published in the first number of the *Revue Mensuelle*, the following conclusions are reached by the speaker: Animals are already in possession of two distinctive elements of language: (1) the spontaneous, reflex cry of emotion and of want, and (2) the intentional cry of advertisement, menace, or appeal. From these two sorts of sounds man, endowed with a vocal apparatus still more perfect and cerebral faculties less limited, has created a great number of variants by means of prolongation, reduplication, and intonation. The cry of appeal is the germ of demonstrative roots prelude to pronouns, names of number, sex, and distance; the emotional cry, of which our interjections are only the debris, combining with the demonstratives, prepare the outlines of the proposition and form the verb and the noun of action and of state. Imitation, direct or symbolical (necessarily only approximative) of the noises of surrounding nature, in a word, onomatopœia, furnishes the elements of attributive roots out of which are to grow names of objects, special verbs, and their derivatives. Analogy and metaphor complete the vocabulary in applying to phenomena of touch, sight, odor, and taste qualificatives derived by onomatopœia. Then comes reason, which eliminating the greater part of these inconvenient riches, adopts a greater or less number of sounds already reduced to one vague and generic sound. Then by derivation,

suffixing, composition, it causes to spring out of these root-sounds indefinite lines of words, which are of all degrees of relationship among themselves, which grammar proceeds to distribute into categories, called parts of speech. It can be shown how the grammatical forms, casual and personal terminations, shades of conjugation are produced by atrophy of syllables affixed or suffixed to the radical syllable. A certain part of the development of language is also due to a sort of blind force, to nature, as we say, and part to intelligence, either individual or collective. The constitution of grammar detaches linguistics from zoölogy properly so called and brings it within the area of history. But this historic area cannot in any manner be shut off from anthropology, for it is only an appendix to natural history.

Dr. Dorsey's volume on the Cegiha language, though bearing date 1890, did not appear until late in 1891. Furthermore, although it is entitled "The Cegiha Language," the work is devoted especially to myths, stories, and letters, and gives, with text, interlinear translation, and free rendering, nearly two hundred and fifty separate literary productions. This embraces the work of many years, and will furnish to the folk-lorist, as well as to the philologist, ample material for study and comparison. The Cegiha language, as used in the volume, refers to the speech of the Omaha and Ponka tribes of the Siouan linguistic family. The author's researches began among the Cegiha in 1871, and have been carried on unremittingly ever since. During the last twelve years he has been connected with the Bureau of Ethnology in Washington, where his opportunities for study have been unlimited. Special attention is also called to Pilling's bibliography of the Algonkian, Gatschet's Klamath, and Riggs's Dakota dictionary.

The Semitic department of Harvard University, in addition to the linguistic courses in Hebrew, Aramaic, Assyrian, Ethiopic, Arabic, and Phœnician, has established Semitic conferences, a Semitic library, a series of prizes for the encouragement of Semitic studies, and a course of lectures on studies allied to the department. Most significant in this connection is the establishment of a Semitic museum, through the generosity of Mr. Jacob H. Schiff. Here already are assembled many originals, casts, manuscripts, coins, and photographs, illustrating the writing and the history of Babylon, Assyria, Phœnicia, Palestine, Arabia, and other Semitic lands. The generous donor has also provided means of enlarging the collection.

## TECHNOLOGY.

In his course of lectures on prehistoric industries M. Adrien de Mortillet makes this neat classification of tools:

*I. Cutting tools.*

| | |
|---|---|
| Acting by pressure | The knife, scissors, or shears.<br>The drawing knife. |
| Acting by a blow | The ax or hatchet, the adze.<br>The chisel or gouge. |
| Acting by friction | The saw. |

*II. Rasping tools.*

| | |
|---|---|
| Acting by pressure and by friction | The scraper (racloir et grattoir).<br>The rasp and the file.<br>Polishers, whetstones, burnishers, and smoothing tools. |

*III. Striking and crushing tools.*

| | |
|---|---|
| Acting by a blow | The hammer. |
| Acting by pressure and by friction | Crushers, to break like flax.<br>Grinding stones, mills. |

*IV. Perforating tools.*

| | |
|---|---|
| Acting by a blow | The pick-ax. |
| Acting by pressure and by friction | Bodkins, awls, piercers, gimlets, augers, etc.<br>Drill, borers. |

An excellent example of the profit to be derived from the care and publication of the material of the older explorers is Mr. Charles H. Read's paper on the collection of ethnographical specimens found during Vancouver's voyage, 1790–1795, plate xi, in vol. XXI, *Journal of the Anthropological Institute.* This plate shows a Mexican atlatl, or throwing stick, but very short, from Lower California, to be held in either hand, as distinguished from the Alaskan specimens made for either hand. The bows are from Oregon or Washington.

The curator of the department of ethnology in the U. S. National Museum has instituted and encouraged a series of experiments so as to reproduce with facility all savage arts. In the American Anthropologist, with the collaboration of several other members of the society, the entire technique of the arrow is worked out. The same process has been followed with fire-making, bow-making, basketry, and the manufacture of stone implements, by Messrs. Hough, Murdoch, and McGuire. Mr. Holmes's papers on so-called paleolithic implements should be here included. It is held that in this way alone can modern ethnology be made to offer true explanations of the mode of life among ancient primitive peoples.

A model description of an art is Mr. Thomas Wardle's paper in the *Journal of the Society of Arts* on the Tussur silk of India and China. It is difficult to say whether in the natural history of the moths, the elaboration of the art, or the description of the native silk culturist the author is most happy. Not only the Indian moths are described but an extended list of silk-producing lepidoptera is brought to the present date. The methods of treatment by extremely simple native processes is furnished, along with European treatment. The ethnologist will be charmed with the account given of the Santals.

M. Philippe Salmon has constructed an elaborate table of the subdivisions of the neolithic period of the Stone Age, especially in France (Rev. Mens. de l'École d'Anthropologie, Paris i, 26), dividing it into (1) Carnacean (Carnac, Morbihan); (2) Chasseo-Robenhausian (Chassy and Robenhausen); and (3) Champignienne (Champigny). The finesse of this division is too great for repetition here and one wonders whether the lines of demarcation will not disappear with further exploration.

A much more useful analysis of the palæo-ethnic period in Europe is that of M. G. de Mortillet in *Revue Mensuelle*, given below:

*Classification palethnologique by G. de Mortillet.*

| Temps. | | | Ages. | Périodes. | Époques. |
|---|---|---|---|---|---|
| Actuels. | | Historiques. | du Fer. | Mérovingienne. | Wabénienne.<br>Franque.—Burgonde.<br>Germanique. |
| | | | | Romaine. | Champdolienne.<br>Décadence Romaine. |
| | | | | | Lugdunienne.<br>Beau temps Romain. |
| | | Protohistoriques. | | Galatienne.<br>Etrusque. | Marnienne.<br>Gauloise.<br>3e Lacustre. |
| | | | | | Hallstattienne.<br>Des Tumulus.<br>1re du Fer. |
| | | | du Bronze. | Bohémienne. | Larnaudienne.<br>2e Lacustre, majeure partie. |
| | | | | | Morgienne.<br>2e Lacustre, partie. |
| | | Préhistoriques. | de la Pierre. | Néolithique.<br>Pierre polie. | Robenhausienne.<br>Des Dolmens.<br>1re Lacustre. |
| | | | | | Campignienne.<br>Des Kjoekkenmoeddings. |
| Géologiques. | Quaternaires. Supérieur. | | | Paléolithique.<br>Pierre taillée. | Magdalénienne.<br>Des Cavernes, majeure partie.<br>Du Renne, presque totalité. |
| | | | | | Solutréenne.<br>Du Renne et du Mammouth, partie.<br>Menchecourienne. |
| | Moyen. | | | | Moustérienne.<br>Du Grand Ours des cavernes. |
| | Inférieur. | | | | Acheuléenne.<br>Du Mammouth, partie.<br>De l'*Elephas antiquus*, fin. |
| | | | | | Chelléenne.<br>De l'*Elephas antiquus*. |
| | Tertiaires. | Originels. | | Eolithique. | Puycournienne.<br>Miocène supérieur. |
| | | | | | Thenaisienne.<br>Miocène inférieur.<br>Oligocène. |

A remarkable series of lucky finds were made on the Hopewell farm, near Chillicothe, Ross County, Ohio, by Mr. Warren K. Moorhead, director of the World's Fair archæological expedition at that point. Not only were new forms of objects discovered, but old forms were collected by thousands. The exciting part of the exploration was the finding of hundreds of copper objects, many of them of such uniform thinness as to raise the question of their European origin.

The Drexel Institute, founded in Philadelphia by the liberality of Mr. Anthony J. Drexel, will be devoted to the encouragement of technical industries. The museum will be administered on the plan of South Kensington.

Before the Tennessee Historical Society the Hon. Gates P. Thurston delivered a short course of lectures on the archæology of Tennessee.

SOCIOLOGY.

Economic science as a branch of sociology is the all-absorbing study of the time. There is not space to enumerate the separate books and papers on this subject, but every reader should know the general resources of the study. Section F, British Association, Economic Science and Statistics List of Papers, p. xix.

Among the political leaders of France, as well as in the Société d'Anthropologie, no other question seems to be of such importance as that of the decrease in natality throughout the Republic. M. Chervin sums up the results of an inquiry in the department of Loir-et-Garonne in the *Bulletin de la Société d'Anthropologie* (4 ser., II, 42–78). There results the demonstration that in this rich department it is the most wealthy that have the smallest number of children, and in the most thriving part of the department the average of children to a family is one. Among the causes of this paucity M. Chervin finds that the well-to-do peasant and farmer wills it to be so, and he believes that no legislation will effect a radical change. Believing that quality and that early deaths become a potent factor in the decline of population, to M. Chervin the saving and perfecting of lives already created is the feasible method of strengthening the population. Assistance and hygiene are the practical methods of relief.

M. Bertillon (*id.*, 366–385), regarding the terrible dangers to which the phenomenally low natality in France exposes her, and believing that the evils of alcoholism, tobacco, and syphilis have only a subsidiary influence, makes the following statement: "That which renders the natality of France so feeble is the voluntary sterility of families having some property. Such families are exceptionally numerous in France. They know that the sure way to keep their property is to have only one child, and a sure way to lose it is to have more than two. One way, therefore, to save France is to remove the cause of feeble natality and to make it more desirable in the way of relief from taxation and increased security of property to have three children than one." In

the older settlements of our own country attention has frequently been called to the decline in the number of large families.

Dr. Robert Fletcher has brought together, in his address before the Anthropological Society of Washington as retiring president, the results of a careful study of the new school of criminal anthropology. By criminal anthropology is meant the study of the being who, in consequence of physical conformation, hereditary taint, or surroundings of vice, poverty, and ill example, yields to temptation and begins a career of crime. It is to study the anatomy, the physiology, the hygiene of the criminal, his productivity, his capability of amendment, to examine into his condition, and to recognize his rights.

An indispensable work to students of the history of human marriage is Edward Westermarck's work, published by Macmillan. The author, it is true, is at issue with almost every school of anthropology, and for that reason presents the subject from a new point of view, but he has brought together a vast amount of material, and his list of authorities quoted amounts to a full bibliography.

The pedagogic problem has been taken up from the side of anthropology. President G. Stanley Hall, of Clark University, Worcester, Mass., has established a new journal, entitled "*The Pedagogical Seminary*," as an international record of educational literature, institutions, and progress. The second number of vol. I, is devoted largely to children and adolescents, and deserves that the contents be given bodily:

Editorial. G. Stanley Hall.
Notes on the study of infants. G. Stanley Hall.
Contents of children's minds on entering school. *Id.*
The moral and religious training of children and adolescents. *Id*
Childrens' lies. *Id.*
The study of adolescence. Mrs. H. Burnham.
Observations of children at the Worcester Normal School. *Id.*
Anthropological investigations of schools. F. Boas.

Reviews are also given of the following:

The story of a sand pile. By G. Stanley Hall, June, 1888.

Boy life in a Massachusetts town a quarter of a century ago. *Id.* Proc. Am. Antiq. Soc., 1890, p. 107-128.

Rudimentary society among boys. By John Johnson. Overland Monthly, and Johns Hopkins Hist. and Polit. Studies, 1884.

Observations on college seniors. By A. E. Kirkpatrick. Am. J. of Psychol., 1890, 168 pp.

Physical training in American colleges and universities. By E. M. Hartwell. Circular of Information, Bureau of Education, No. 5, 1885, 183 pp.

Physical training conference. *Id.* Boston, 1889, p. 155.

Physical and industrial training of criminals. By H. D. Wey. Industrial Educ. Assoc., N. Y., 1888, p. 50.

Overpressure in the high schools of Denmark. By Dr. Hirtel. London, 1885. 148 pp.

The growth of children. By H. P. Bowditch. Eighth An. Rept. Mass. Bd. of Health, Boston, 1877; also Tenth An. Rept.

Why do we measure mankind! Francis Galton. Lippincott's, February, 1890; also the reports of Mr. Galton's laboratory work and measuring apparatus.

Cambridge anthropometry. By John Veron. J. Anthrop. Inst., xviii, 140 pp.

An anthropological cabinet for pedagogic purposes. Prof. Sergi, of the Univ. of Rome. Education, Sept., 1886.

Mental association investigated by experiment. By Cattell and Bryant. Mind, xiv, 230.

The children: How to study them. By Francis Warner. London, 1887. 80 pp.

Experiments in testing the character of school children. By Mrs. Sophie Bryant. J. Anthrop. Inst., xv, 338.

Mental imagery. Francis Galton. Inquiries into human faculty, p. 83.

Eye-mindedness and ear-mindedness. By Jos. Jastrow. Pop. Sc. Month., xxxiii, p. 597.

A study in mental statistics. Jos. Jastrow.

Replies by teachers to questions respecting mental fatigue. Francis Galton. J. Anthrop. Inst., 1888, p. 157.

On the principle and methods of assigning marks for bodily inefficiency. F. Galton. Nature, Oct. 3, 1889.

Ueber Schulwanderungen. O. Lomberg. Elberfeld, 1887.

Notes on studies of the language of children. By E. C. Sanford.

Die Stipendein und Stiftungen, Convicte, Freitische, etc., in allen Universitäten des deutschen Reichs. Dr. Max Baumgart. Berlin, 1885, p. 760.

Grundsätze und Bedingungen der Ertheilung der Doctorwurde, etc. Baumgart, Berlin, 1888, 328 pp.

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## FOLK-LORE, MYTHOLOGY, AND HIEROLOGY.

The third annual meeting of the American Folk-lore Society was held at the Columbian University, Washington, D. C., on Tuesday and Wednesday, December 29 and 30. This meeting of the society was of especial interest on account of the co-operation of the two anthropological societies of Washington in giving to the sessions a scientific turn. The papers were mostly upon American aboriginal lore. The organ of the society, the *Journal of American Folk-lore*, edited by W. W. Newell, devotes much space in each number to bibliography. Branches of the American Folk-lore Society are the Louisiana Association of the American Folk-lore Society and the Boston Association of the American Folk-lore Society. An independent organization is the Chicago Folk-lore Society, and there is also a folk-lore section of the Museum of Archæology of the University of Pennsylvania.

The meeting of the International Folk-lore Congress, at Burlington House, London, in October, and the third annual meeting of the American Folk-lore Society in Washington in December, were important events in the evolution of that science. Regarding folk-lore as the archæology of thought and custom, the presidents of both gatherings dwelt on the fact that the mere dilettante collecting stage had now been passed and folk-lorists were engaged in a serious business.

The science of folk-lore has been very much strengthened in Germany by the founding of *Zeitschrift des Vereins für Volkskunde*, which is a new branch of Lazarus and Stanthal's *Zeitschrift für Völkerpsychologie und Sprachwissenschaft*. The carefully prepared bibliography of journals and other works relating to this science accompanying each number obviate the necessity of repeating here the title of every paper that has appeared on this subject.

The friends of the study of comparative religion conducted in the University of Pennsylvania a loan collection of objects used in religious ceremonies, including charms and implements used in divination. The basis of the exhibition was a collection of Oriental idols of the Board of Foreign Missions of the Presbyterian Church of the United States. This is, so far as reported, the first attempt to set up an exhibition of this kind, and could be repeated in almost every city of the United States with happy results, not only with religious objects, but also to illustrate any class of anthropological concepts.

The lectures of Count Goblet d'Alviella on the origin and growth of the conception of God as illustrated by anthropology and history, in the Hibbert Course for 1891, define the limits within which the study of religion may be considered a part of the natural history of man. In these summaries the subject has been made to include the creeds and cults of men and of the world. From the side of the spirit world, the study has been called daimonology, but this term is entirely too narrow. Count d'Alviella employs the word "hierography" as including the study of both creeds and cults. The elements common to all organized religions are:

(1) The belief in the existence of superhuman beings who intervene in a mysterious manner in the destinies of man and the course of nature.

(2) Attempts to draw near to these beings or to escape from them, to forecast the object of their intervention and the form it will take, or to modify their action by conciliation or compulsion.

(3) Recourse to the mediation of certain individuals supposed to have special qualifications for success in such attempts.

(4) The placing of certain customs under the sanction of superhuman powers.

Primarily, religion is defined as "the conception man forms of his relations with the superhuman and mysterious powers on which he believes himself to depend." Further on and growing out of this conception are "the acts which man's primitive conception of superhuman beings and his relation with them lead him to perform."

Commencing with primitive animism, these conceptions have arisen through polydemonism and polytheism, through dualism to monotheism. The outlook in this author's mind is most cheering. On the other hand, the teachings of the École d'Anthropologie are to the effect that under the clear light of science all religions will be banished from the world.

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# THE MOUNDS OF THE MISSISSIPPI VALLEY, HISTORICALLY CONSIDERED.*

By Lucien Carr.

In a paper upon the Prehistoric Remains of Kentucky, published in the first volume of these memoirs, I have expressed the opinion that it was impossible to distinguish between a series of stone implements taken from the mounds in the Mississippi Valley and a similar series made and used by the modern Indians. In fact, so alike are these objects in conception and execution that any attempt to distinguish them, based upon form or finish, must be but the merest guesswork. From the rude knife to the carved and polished "gorget" they may, one and all, have been taken from the inmost recesses of a mound or picked up on the surface amid the débris of a recent Indian village, and the most experienced archæologist, if called upon to decide as to their origin, would have to acknowledge himself at fault.† Nor does this similarity stop with objects made of stone. On the contrary, it is believed to extend to all the articles, of every kind whatsoever, that have thus far been taken from the mounds. Indeed, I might even go further, and as the result of some years of work, as well in the field as in the library, venture the assertion that not only has there not as yet been anything taken from the mounds indicating a higher stage of development than the red Indian of the United States is known to have reached, but that even the mounds themselves, and under this head are included all the earthworks of the Mississippi Valley, were quite within the limits of his efforts.

This conclusion, together with its corollary as to the origin of these structures, is neither new nor original; and yet, in spite of the simple explanation it gives of the mound question, or, perhaps, it might be more correct to say on account of this very simplicity, it has made its way but slowly. It seems difficult to account for this fact except on

* *Memoirs of the Kentucky Geological Survey*, vol. II, 1883; N. S. Shaler, Director.

†Compare Schoolcraft's *Indian Tribes of the United States*, vol. IV, p. 141. Brinton, *Floridian Peninsula*, p. 176: Philadelphia, 1859. M. F. Force, *Some Considerations on the Mound-builders*, p. 72: Cincinnati, 1873. S. F. Haven, in vol. VIII of the Smithsonian *Contributions to Knowledge*, p. 158. Lapham, in vol. VII of same, p. 30.

the ground that those who have written upon this subject, and who have, to a certain extent, molded public opinion, have approached it from one side only. They have usually belonged to the class of practical explorers, and have brought to the investigation a certain number of facts, chiefly cumulative in character; but they have not, as a rule, been possessed of that measure of historical information which is necessary to a correct interpretation of these facts. Being thus, as it were, but half prepared for the work, they have, not unfrequently, given too much play to the imagination, and carried their theories much farther than the facts would warrant. Impressed with the size and character of these remains, or led astray by certain resemblances, fancied or real, to similar objects elsewhere, they have used them as a basis for reconstructing a phase of civilization to which, in point of religious, artistic, and political development, they declare the Indian to have been unequal. From these extreme views there has always been more or less dissent.* Even Mr. Squier, who, in his famous work "The Ancient Monuments of the Mississippi Valley," makes no distinction in these remains, but speaks of the Mound-builders as an "extinct race,"† and contrasts their progress in the arts with the low condition of the modern Indians,‡ is obliged, in a subsequent publication, to modify his views and draw a line of demarkation between the earth-works of western New York and those found in southern Ohio, especially those

* "They" (the earthworks) "differ less in kind than in degree from other remains respecting which history has not been entirely silent:" Haven in vol. VIII of the *Smithsonian Contributions*, p. 158. "There is nothing, indeed, in the magnitude and structure of our Western mounds which a semihunter and semiagricultural population, like that which may be ascribed to the ancestors or Indian predecessors of the existing race, could not have executed:" Schoolcroft's *Indian Tribes of the United States*, vol. I, p. 62. "All these earthworks—and I am inclined to assert the same of the whole of those in the Atlantic States and the majority in the Mississippi Valley—were the production not of some mythical tribe of high civilization in remote antiquity, but of the identical nations found by the whites residing in these regions:" Brinton, *Floridian Peninsula*, p. 176: Philadelphia, 1859. "No doubt that they were erected by the forefathers of the present Indians, as places of refuge against the incursions of their enemies, and of security for their women and children when they were compelled to leave them for the duties of the chase:" Gen. Lewis Cass, in *North American Review* for January, 1826. "Nothing in them which may not have been performed by a savage people:" Gallatin, in *Archæologia Americana* vol. II, p. 149. "The old idea that the Mound-builders were peoples distinct from and other than the Indians of the fifteenth and sixteenth centuries and their progenitors, appears unfounded in fact, and fanciful:" C. C. Jones, in *North American Review* for January, 1874, p. 80. "Mound-builders were tribes of American Indians of the same race with the tribes now living:" M. F. Force at the Congrès International des Americanistes: Luxembourg, 1877. "The progress of discovery seems constantly to diminish the distinction between the ancient and modern races; and it may not be very wide of the truth to assert that they were the same people:" Lapham, in *Smithsonian Contributions to Knowledge*, vol. VII, p. 29.

† *Smithsonian Contributions to Knowledge*, vol. I, p. 306: Washington, 1848.

‡ *l. c.*, pp. 188 and 242.

which he styles religious or "sacred inclosures." The former of these, he thinks, were erected by the recent Indians, and he supports this view by a chain of reasoning that is believed to be unanswerable. In it he institutes a comparison between the "relics of art and traces of occupancy" found within them, and those which mark the sites of towns and forts that are known to have been occupied by the Indians, and pronounces them to be identical. To this powerful argument, drawn from what may, not inaptly, be termed the facts of the mound, he adds very copious notes as to the origin and use of such structures among the people of all ages and countries, though, of course, with special reference to those that are known to have been erected by the American Indians. In this historical retrospect he permits the facts to speak for themselves with most commendable impartiality, even though, as he frankly admits, they led to the conclusion, little anticipated when he started on the trip of exploration, "that the earth-works of western New York were erected by the Iroquois or their western neighbors, and do not possess an antiquity going far back of the discovery." *

To this conclusion, so far as it goes, I certainly do not object. Unfortunately, however, it stops short of the mark; and this is the more to be regretted, inasmuch as it is believed that the line of argument by which Mr. Squier convinced himself that the defensive works of western New York were erected by the modern Indians would, if it had been applied to the earth-works of the Mississippi Valley of every kind whatsoever—to the so-called sacred inclosures not less than to the hill forts—have led him to precisely the same conclusion. The two propositions rest upon essentially the same foundation, and, as we shall see later on, must stand or fall together.

Before beginning this task, however, it may be well to premise that it is not intended, in the course of this investigation, to assert that the mounds were built by any particular tribe or tribes of Indians, or at any particular time; neither is it claimed that each and every tribe living within the Mississippi Valley erected such structures. So far as my present purpose is concerned, they may have been built by any tribe that can be shown to have occupied the regions where they are ound, and at any time during the period of such occupancy. All that I intend to assert is, that, admitting everything that can be reasonably claimed by the most enthusiastic advocate of the superior civilization of the Mound-builders, there is no reason why the red Indians of the Mississippi Valley, judging from what we know, historically, of their development, could not have thrown up these works. This proposition is not as complete as could be desired, and yet it probably embodies all that can ever be proven on this subject. Ability and performance

* "Aboriginal Monuments of the State of New York," in *Smithsonian Contributions to Knowledge*, vol. II, p. 83: Washington, 1851.

do not always go hand in hand, and the fact that a people could have executed a piece of work does not, by any means, authorize the conclusion that they did so. Between the two there is, logically speaking, a wide gulf which can only be successfully passed by a resort to what is known as the law of probabilities. This is unfortunate, but under the circumstances it is unavoidable; and although it will, unquestionably, cause our conclusion to lack somewhat of the force of a scientific demonstration, yet it is believed that after making all due allowance, there will remain such a volume of evidence in favor of our proposition as to justify a favorable decision. In all human probability it will never be known who built these mounds in the same sense in which it is known who built Westminster Abbey; but if it can be demonstrated that the people who erected them were in the same (neolithic) stage of civilization that the Indians are known to have attained, and if, further, it can be shown on undoubted historic authority that these Indians built both mounds and earth-works, which differ in degree but not in kind from similar structures that are assumed to have been the work of an extinct people, whom we have called the Mound-builders, then it must be acknowledged that a strong argument is made out in favor of the identity of the origin of the two systems of works. To reject this conclusion without some positive evidence to the contrary would involve as great an absurdity as it would be to maintain, supposing all record of the fact to be lost, that Westminster Abbey was built by a people belonging to a different race from that which is known, formerly, to have lived in London, and for no better reason than because the English of to-day have ceased to build such abbeys.

This much being premised, we are now ready to take up the thread of our investigation; and by way of beginning, let us examine into the accounts, given by the early writers, of the mode of life and the civil and religious polity of the Indians in order to find out whether there is anything that would lead us to conclude, *a priori*, that it was impossible for them to have erected these works. On the part of those who hold affirmative views on this point, it is contended that a system of works of the size, say of those in the Scioto Valley, would have required the united labor of many persons for a long period of time, and that as the Indians were hunters—not agriculturists,—and averse to labor, they could not have carried it on, for the reason that, owing to their wandering and precarious mode of life, the means of subsistence would have failed them, even if there had been some central authority, or some controlling motive strong enough to impel them to the undertaking.* This is believed to be a fair statement of the argument, and if well founded, it would be decisive of the matter. Upon examina-

*Squier, *Ancient Monuments of the Mississippi Valley*, pp. 45 and 301 *et seq.*: Washington, 1848. Foster, *Prehistoric Races of the United States*, p. 346: Chicago, 1873. Baldwin, *Ancient America*, p. 34: New York, 1872. McLean, *Mound-builders*, pp. 124 and 5: Cincinnati, 1879.

tion however it will be seen that it is based upon the assumption that the Mound-builders were an agricultural people, and lived under a strongly centralized form of government, no matter whether that government was one of force, or of opinion founded upon policy or religion. This assumption is probably not far from the truth; but to have any weight in this discussion, it must carry with it, as a correlative, the further admission that the Indian was *not* an agriculturist, and was *not* subject to any such central authority, or controlled by any such impelling motive. This of course is not admitted, and it is precisely upon these points that the issue is to be joined.

### I.—THE INDIAN AS AN AGRICULTURIST.

Taking up, in their order, the requirements that are admitted to have been possessed by the builders of these mounds, and which are popularly supposed to have been wanting in the Indian, we are met, first of all, with the statement, made either directly or by implication, that he was not an agriculturist, but depended almost entirely upon the chase for the means of subsistence.* True, there exists a vague notion that succotash and hominy were not unknown in the aboriginal cuisine, and there may be those of us who are sufficiently skilled in culinary matters to say that these succulent dishes are made of Indian corn; but of the substantial truth of the above statement there is little or no doubt, even among those who have taken the trouble to write on the subject. Exactly why this is so, when all the records tell us that the early colonists in New England, Virginia, and elsewhere throughout the eastern portion of the United States owed their lives, on more than one occasion, to the timely supplies of corn begged, bought, or stolen, from the natives,† is something of a mystery, though perhaps it is

* *Ancient Monuments of the Mississippi Valley*, p. 45. Baldwin, *Ancient America*, p. 34. Foster, *Prehistoric Races of the United States*, p. 300. Schoolcraft's *Indian Tribes of the United States*, vol. VI, p. 183. Gookin in vol. I of the first series of the *Massachusetts Historical Collections*, p. 149. Colden's *History of the Five Nations*, p. 13: London, 1767.

† Plusieurs nations sauvages s'etablirent sur le Mississippi assez pres de la Nouvelle Orleans et comme la plupart de ces Peuples sont dans l'usage de cultiver la terre, ils defricherent des grands terreins, ce qui fut une resource pour cette ville a laquelle ils ont souvent fourni des vivres dans le besoin:" Charlevoix, *Histoire de la Nouvelle France*, vol. IV, p. 198: Paris, 1744. "I was safely conducted to Jamestowne, where I found about eight and thirtie poore and sicke creatures; - - - such was the weakness of this poore commonwealthe as, had the salvages not fed us we directlie had starved. And this relyfe, most gracious Queene, was commonly brought by this lady Pocahontas; - - - during the time of two or three yeares, shee next, under God, was still the instrument to preserve this colonie from death, famine and utter confusion:" Capt. Smith, Relation to Queene Anne in *History of Virginia*, p. 121: London, 1632. "By selling them corn, when pinched with famine, they" (the Indians) "relieved their distresses and prevented them from perishing in a strange land and uncultivated wilderness:" Trumbull, *Connecticut*, vol. I, p. 47: Hartford, 1797. "They got in this vioage, in one place and other, about 26 or 28 hogsheads of corne and beanes:" Bradford's History of Plymouth Plantation, in *Mass. Hist. Coll.*, vol.

not more inexplicable than it is to account for the efforts, at this late day, of earnest and intelligent men to have the Indian shown how to raise corn, and this in face of the fact that he has cultivated that most useful cereal for hundreds of years, and actually taught our ancestors the process.* These are but samples of the loose way of thinking that prevails upon this and kindred topics, and it must be our excuse, if any be needed, for going into the matter somewhat in detail. Fortunately, the material for this purpose is quite abundant, and the testimony so uniform that of the main fact—the cultivation of corn in greater or less quantities by all the tribes living east of the Mississippi and south of the St. Lawrence and the Great Lakes—there can not be a shadow of doubt.† All the early writers are agreed upon the point, and there is no room for a difference of opinion, except, perhaps, in regard to the amount grown. Upon this point, too, the evidence is explicit. Instead of cultivating it in small patches as a summer luxury, it can be shown, on undoubted authority, that everywhere, within the limits named, the Indian looked upon it as a staple article of food, both in summer and winter; that he cultivated it in

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III, fourth series, p. 129. "Others fell to plaine stealing, both night and day, from ye Indeans, of which they grievously complained. - - - Yea, in ye end they were faine to hange one of their men, whom they could not reclaime from stealing:" *Ibid.*, p. 130. "Sometimes these savages" (the Hurons and Onattawacs at Missilmakinac) "sell their corn very dear:" La Hontan, *Voyages*, vol. I, p. 90: London, 1703. See also Geo. Percy, *Virginia*, in *Purchas Pilgrims*, book 9, chap. 2; and Winslow, *Good News from New England* in same, book 10, chap. 5: London, 1625.

* "Afterwards they (as many as were able) began to plant the corne, in which servise Squanto stood them in great stead, showing them both ye manner how to set it, and after how to dress and tend it." Bradford's History of Plymouth Plantation in Publications *Mass. Hist. Soc.*, vol. III of 4th series, p. 100. "Instructed them in the manner of planting and dressing the Indian corn." Trumbull's *History of Connecticut*, vol. I, p. 46, Hartford, 1797.

† "All the tribes east of the Mississippi were more or less agricultural. They all raised corn, beans, squashes and melons." Force, *Some Considerations on the Mound-builders*, p. 70. "Le mais ainsi que Je viens de le dire est la nourriture commune de tous les sauvages sedentaires depuis le fond du Brésil Jusques aux extremitez du Canada." Lafitau, *Moeurs des Sauvages Ameriquains*, vol. II, p. 64: Paris, 1724. "The whole of the tribes situated in the Mississippi Valley, in Ohio, and the Lakes reaching on both sides of the Alleghanies, quite to Massachusetts and other parts of New England, cultivated Indian corn. It was the staple product." Schoolcraft, vol. I, p. 80. All the nations I have known, and who inhabit from the sea as far as the Illinois, and even farther, which is a space of about 1,500 miles, carefully cultivate the maiz corn, which they make their principal subsistence." Du Pratz, *History of Louisiana*, vol. II, p. 239: London, 1763. "The territory over which cultivation had extended is that which is bounded on the east by the Atlantic, on the south by the Gulf of Mexico, on the west generally by the Mississippi, or, perhaps more properly, by the prairies, on the north, it may be said by the nature of the climate." *Archæologia Americana* (Gallatin), vol. II, p. 149. "It was found in cultivation from the southern extremity of Chili to the fiftieth parallel of north latitude, beyond which limits the low temperature renders it an uncertain crop." Brinton, *Myths of the New World*, p. 23: New York, 1876. See also *Relation*, A. D. 1626, p. 2: Quebec, 1858.

large fields, and understood and appreciated the benefits arising from the use of fertilizers.* Indeed such was his proficiency and industry, that even with the rude and imperfect implements at his disposal,† he not only raised corn enough for his own use, but, as a rule, had some to spare to his needy neighbors, both red and white.‡ Under ordinary circumstances it would only be necessary to establish this fact in order to prove, beyond cavil, that the red Indian was an agriculturist in the very highest acceptation of that term, and that in this respect, at least, he stood upon the same footing as the mound-builders. In the present instance however this is not the case. Not only is it not sufficient to prove that the Indians were husbandmen in order to raise them to this level, but we are called upon to show that among them the men labored in the fields as well as the women. Indeed, we are told by a writer, from whom I differ with many misgivings, that in this respect there was a very great difference between the mound-builders and the recent Indians; and although the difference is said not to be absolute, yet it is gravely asserted that among the former "the men must have labored, whilst among the latter labor is left to the squaws."§ Statements like these, unsupported by evidence, do not carry much weight; and if this investigation were intended to be a mere trial of dialectical skill, and not an earnest search after the truth, it would be sufficient to pass them by with a simple denial—all the reply that they are logically entitled

* "Also he tould them excepte they gott fish, and set with it (in the old grounds) it would come to nothing." Bradford's History of Plymouth Plantation, in vol. III, of the 4th series of *Mass. Hist. Coll.*, p. 100. The Iroquois "manure a great deal of ground for sowing their Indian corn." Hennepin, *A new Discovery of a vast Country in America*, etc., vol. I, p. 18: London, 1698. "Tous ces peuples" (Armouchiquois, *Virginiens*, etc.)" "engraissent leurs champs de coquillages de poissons." Lescarbot, vol. II, p. 834: Paris, 1612. "They never dung their land, only when they would sow." Laudonnière. First Attempt of the French to Colonize Florida, in *Hist. Coll. Louisiana.*, new series, p. 174: New York, 1869.

† "Use wooden howes." Williams' Key, p. 130. "Spades made of hard wood used in agriculture." Bossu, *Travels Through Louisiana*, p. 224: London, 1771. "Florida Indians dig their ground with an instrument of wood which is fashioned like a broad mattock." Laudonnière in *Hist. Coll. Louisiana*, new series, p. 174: New York, 1869. "Ils ont un instrument de bois fort dur, faict en façon d'une besche." Champlain, vol. I, p. 95: Paris, 1830. "Il leur suffit d'un morceau de bois recourbé de trois doigts de largeur, attaché a un long manche qui leur sert a sarcler la terre et a la remuer legerement." Lafitau, *Moeurs des Sauvages Ameriquains*, vol. II, p. 76. "Use hoes made of shoulder blade of animals fixed on staves." Romans, *East and West Florida*, p. 119. "Use shoulder blade of a deer or a tortoise shell, sharpened upon a stone and fastened to a stick instead of a hoe." Loskiel, *Missions in North America*, p. 67: London, 1794. See also Joutel in *Hist. Coll. Louisiana*, part I, p. 149, etc.

‡ *Relation de la Nouvelle France* en l'année 1641, p. 81: Quebec, 1858. Sagard, *Voyage des Hurons*, pp. 125, 134: Paris, 1632. Capt. John Smith, Description of New England in *Mass. Hist. Coll.*, vol. VI, of 3d series, p. 120. La Hontain, *Voyages*, vol. I, p. 105: London, 1703. Charlevoix, *Letters*, p. 175: London, 1763.

§ *Some Considerations on the Mound-builders.* By M. F. Force. Pamphlet, p. 72: Cincinnati, 1873.

to. But this mode of procedure would not answer the purposes of this inquiry, and hence I am induced to accord them a more respectful consideration; and I do this the more willingly inasmuch as it agrees with my general plan of admitting everything that can be reasonably claimed in behalf of the mound-builders, whilst at the same time it affords an opportunity of examining into the correctness of the usually received opinion "that the Indian considered labor as derogatory, and left it to the women."*

Before beginning this branch of the inquiry, however, it is necessary to come to some understanding as to the meaning to be given to the word "labor," otherwise we shall be at cross-purposes throughout the whole of the investigation. Used in its broadest sense, the term includes hunting and fishing—occupations which undoubtedly belonged to the men, and which, when followed, not as a pastime, but for the purpose of gaining a subsistence, involved labor of the very hardest kind.† If to this it be added that the Indian warrior was expected to do all the fighting, it will be seen that, at a very moderate estimate, he had work enough on his hands to keep him reasonably busy. As an evidence of the absorbing nature of these occupations, it may be said that, to-day, in some countries of Continental Europe in which the state of war is the exception and not the rule, as it was among the Indians, the performance of the one duty of military service alone is considered to be a sufficient reason for withdrawing all able-bodied males, within certain ages, from every kind of productive labor during the term of such service, even though the whole of it be passed in a time of profound peace. Among these nations, and they are some of the most highly civilized in Europe, it is no exaggeration to say that labor, using that word in its broadest sense, is left to the women far more completely than it ever was among the Indians; for the Indian, when not actually engaged in warfare, did hunt and fish, and contribute to this extent, at least, to the general welfare, whilst his European counterpart is not allowed to engage in productive labor of any kind whatsoever during his term of military service. But there is another and a narrower sense, in which the word is taken to mean simply field-work, or work necessary to the growth and production of corn; and it is this signification that is

* *Archæologia Americana*, vol. II, p. 151. Stoddard, *Sketches of Louisiana*, p. 411: Philadelphia, 1812. Colden, *Five Nations*, vol. I, p. 13: London, 1747. Foster, *Prehistoric Races of the United States*, p. 300: Chicago, 1873. Charlevoix, *Letters*, vol. II, p. 126: London, 1761.

† "Fatigues of hunting wear out the body and constitution far more than manual labor." Heckewelder, *Historical Account of the Indian Nations*, p. 146. "Their manner of rambling through the woods to kill deer is a very laborious exercise, as they frequently walk twenty-five or thirty miles through rough and smooth grounds, and fasting before they return back to camp loaded." Adair, *History of the American Indians*, p. 402: London, 1775. "Indian affects not to feel the weight of dragging a deer 100 to 150 pounds weight through a considerable tract of forest." Loskiel, *Missions in American*, p. 107: London, 1794.

usually given to it by writers on this subject, and it is in this sense that it will be hereafter used in the course of this investigation. Substituting, then, the more specialized form of expression for the general term, and the sentence will read as follows: Among the Indians field-work was considered derogatory, and left to the women. In this restricted shape the statement is not so objectionable; and yet, even in this form, it is believed to be altogether too sweeping. That in some particular years this work may, from some cause, have been left to the women, is of course very probable—the necessities of war or the chase might at any time render this unavoidable in any tribe; and it may also be true that in the division of labor between the sexes, made necessary by the duty of providing for the family, this share, among certain tribes, fell to her lot; but that it was either onerous,* or compulsory,† or that the custom, if such it can be called, was general, or that it was adhered to very strictly, even among the tribes in which it can be said to have prevailed, is not for a moment admitted. Take for example the Iroquois or Six Nations, the only people among whom, so far as I know, it can not be shown that the warriors did take some part either in clearing the ground or in cultivating the crop, and we find that even among them the work was not left exclusively to the women, but that it was shared by the children and the old men, as well as the slaves, of whom they seem to have had a goodly number.‡ Singularly enough, too, the reason given by the old chronicler why the men took

* "Labor in the fields employs women six weeks in twelve months, while the labor of the husband to maintain his family lasts throughout the year." Heckewelder, *Historical Account of the Indian Nations*, p. 142. "The work of the women is not hard or difficult. - - - The tilling of the ground at home - - - is frequently done by female parties, much in the manner of those husking, quilting, and other frolics. - - - The labor is thus quickly and easily performed; when it is over, and sometimes in intervals, they sit down to enjoy themselves by feasting on some good victuals prepared for them by the person or family for whom they work, etc." *Ibid.*, pp. 144, 145. Consult also Williams's Key to the Indian Language, in *Collections of the Rhode Island Hist. Soc.*, p. 92. Sagard, *Voyage des Hurons*, p. 130: Paris, 1632. Joutel, Journal in *Hist. Coll. of Louisiana*, part I, p. 149. Lafitau, *Moeurs des Sauvages Ameriquains*, vol. II, p. 77: Paris, 1724.

† "Elles travaillent ordinairement plus que les hommes, encore qu'elle n'y soient point forcées n'y contraintes." Sagard, *Voyage des Hurons*, p. 130: Paris, 1632. "Not only voluntary, but cheerfully performed." Heckewelder, p. 142. "In the spring the corn field is planted by her and the youngsters in a vein of gaiety and frolic. It is done in a few hours, and taken care of in the same spirit. It is perfectly voluntary labor, and she would not be scolded for omitting it; for all labor with Indians is voluntary." Schoolcraft, *Indian Tribes of the United States*, vol. II, p. 64. "Au reste ce travail n'est pas penible." Charlevoix, *Nouvelle France*, vol. III, p. 23. See also Life of Mary Jemison, a captive among the Iroquois, who says, pp. 69, 70, that the "lot of the Indian women is not harder than that of white women:" New York, 1856.

‡ "If any of his children be killed or taken by the enemy, he is presently furnished with as many slaves as he has occasion for." La Hontan, vol. II, p. 7: London, 1703. "Women slaves are employed to sow and reap the Indian corn; and the men slaves have for their business the hunting and shooting when there is any

no part in the labor, *i. e.*, because "they were always at war or hunting," is the same that is to-day made to do duty in justifying the existence of a similar condition of affairs among people who boast not a little of their civilization.

Among most of the other tribes north of the Ohio and south of the St. Lawrence, Huron as well as Algonquin, the men not only habitually cleared the ground*—no small undertaking, be it understood, in a heavily-timbered region—but they frequently took part in what is technically known as "working" the crop, and also aided in the labors of the harvest field. This may not have been a part of their duty, but we have the authority of Charlevoix for saying that when asked to aid in gathering the crop "they did not scorn to lend a helping hand."†

On this point, however, it is necessary to make haste slowly, as our guides not only contradict each other, but are very often at odds with themselves, and it requires some judgment to pick our way amid the conflicting statements. As an instance of some of the least of the difficulties that beset out path at this stage of the inquiry, let us take the younger Bartram, whose account of his travels among the Indians of the Gulf States is one of the most trustworthy that has come down to us. Time and again, in the course of his narrative, he speaks of the part taken by the men in the work of raising corn,‡ and yet, on page 513, he tells us that they "perform nothing except erecting their mean habitations, forming their canoes, stone pipes, tambour, eagle's tail, or standard, and some other trifling matters, for war and hunting are their principal employments." In Vander Donck's New Netherlands there is an instance even more to the point, though it is no means an extreme case. On one page he tells us that the Indians "subsist by hunting and fishing throughout the year," having apparently forgotten that in a previous chapter he had said that "mush or *sapaen*" was their common food, and that they rarely pass a day without it unless they are on a journey or hunting.§ Strictly speaking, the statements

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fatigue, tho' their masters will very often help them." *Ibid.*, p. 18. "Therefore the plantation work," among the Iroquois, "is left for the women and slaves to look after." Lawson, *Carolina*, p. 188. London, 1718. See also Lafitau, vol. II, p. 308: Paris, 1724. Charlevoix, Letters, p. 162: London, 1763. Hennepin, *A New Discovery of a Vast Country*, etc., vol. I, pp. 43, 215, and 231: London, 1698. John Bartram, p. 79: London, 1751. By almost all of the old chroniclers "captive" and "slave" are used as convertible terms.

*"Ce sont les hommes par toute l'Amerique qui sont chargés de marquer les champs et d'en abattre les gros arbres. Ce sont eux aussi, qui en tout temps sont obligés de couper le gros bois," etc.: Lafitau, *Moeurs des Sauvages Ameriquains*, vol. II, p. 109: Paris, 1724. "The qualifications of man - - - to build cottages, to fell trees," etc.: La Hontan, *Voyages*, vol. II, p. 9: London, 1703. Compare La Potherie, vol. III, p. 18: Paris, 1753.

† Charlevoix, *Letters*, p. 237: London, 1763.

‡ *Travels through North and South Carolina, Georgia, East and West Florida, etc.*, pp. 194, 512, 517: Philadelphia, 1791.

§ Vander Donck's New Netherlands, in *Collections New York Hist. Soc.*, vol. I, of new series, pp. 193 and 197.

in the first of these instances are not contradictory, for our author is speaking of manufactures when he says the men do "nothing, etc.;" and it is possible, in that latitude, for a man to raise a crop of corn and work it well too, and yet spend the most of his time hunting and fighting. To admit this however is to credit the old chronicler with a degree of refinement in the use of language to which he is believed to have been an utter stranger. In the second instance, there is no room for any such compromise. The two statement conflict, and can not be reconciled by any amount of verbal hair spitting. In neither case, be it observed, do the facts justify the inference that the field-work was left exclusively to the women, as that conclusion is manifestly impossible, so long as it is admitted that the men took any part in the labor, be it ever so small, at any stage of the process; and yet it is precisely upon these and similar statements that this conclusion is based. Without stopping now to inquire into the *rationale* of these contradictions, sometimes only apparent, but often very real, it will be sufficient to say that they have not sprung from any wish to mislead, but have rather grown out of the fact that when these old writers began to generalize, they fell into the common error of failing to make du allowance for the many exceptions to the rule they were laying down. In all such cases the true way out of the difficulty is not to accept one statement to the exclusion of the other; neither will it aid us to offset one by the other, and so reject both, but rather we ought to qualify the general conclusion by the exceptions, and thus bring it within the bounds marked out by the facts. Believing this to be the true method of pursuing this investigation, it will be incumbent on me to examine into the history of each tribe or group of tribes separately, in order to find out whether the men, *i. e.*, the warriors, took any part in the field-work, and if so, to what extent. If, in the course of the inquiry, it should be shown that, in any tribe, at any time, the men did take some part in this work, no matter how insignificant it may have been, then it is evident that at that time, in that particular tribe, the field-work was *not* left exclusively to the women, whatever may be said to the contrary by the author who tells the story. It must not however be forgotten that although this statement as to the actual condition of a large majority of the tribes living east of the Mississippi and south of the St. Lawrence is believed to be true, yet it is not denied that there were many instances in which this labor was practically left to the women, owing to the fact that the men were away from home hunting or fighting. This fact was unfortunately of frequent recurrence; but as it was the result of an accidental and not of a permanent condition of affairs, it would hardly be fair to ascribe it to the existence of any custom or to any belief in the derogatory character of the work.

Beginning with the Hurons, of Canada, we find that in A. D. 1535 a band of the Iroquois branch of that family was living in the stockaded

village of Hochelaga, now Montreal. According to Cartier* "they had good and large fields full of corn, - - - which they preserved in garrets at the top of their houses." He also tells us that they are "given to husbandrie, - - - but are no men of great labor; and that they digge their ground with certain pieces of wood as big as halfe a sword, on which ground groweth their corne." The women are said "to work more than the men - - - in tilling and husbanding the ground." Champlain,† A. D. 1610, speaking of this same family of tribes, especially of those living north of the St. Lawrence, and in the peninsula lying between lakes Huron, Erie, and Ontario, repeats, substantially, what is said about their houses and fortified villages,‡ and adds that most of them cultivated corn, which was their principal article of food, and which they also exchanged for skins with the hunter tribes living to the north. They stored it in the tops of their houses, and cultivated it in quantities, so that they might have on hand a supply large enough to last three or four years, in case of the failure of the crops in some bad season.§ The women are said to have cultivated the ground and planted corn, whilst the men hunted, fished, went to war, and built their cabins. When this was done, they went off on trading expeditions among other tribes, sometimes extending their trips to the distance of 400 or 500 leagues. All this is confirmed by Sagard,‖ who adds some interesting details as to the tenure of lands¶ and the method of cultivating the corn. He also tells us that the men cleared the ground, and that this was done with great difficulty, as they had no suitable implements with which to work. This process was the same among all the Indian tribes, and as it is practically in

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*Cartier in Hakluyt's *Voyages*, vol. III, pp. 271, *et seq.:* London, 1810.

† *Voyages* de Champlain, Livre Quatrième, chapter viii: Paris, 1632.

‡ Compare Relation de la Nouvelle France en l' année, 1626, p. 2: Quebec, 1858. Lafitau, *Moeurs des Sauvages Ameriquains*, vol. II, p. 3, *et seq.:* Paris, 1724. La Hontan, *Voyages*, vol. II, p. 6: London, 1703. Charlevoix, *Letters*, pp. 240-241: London, 1763. Sagard, *Voyage des Hurons*, pp. 115-117: Paris, 1632.

§ *Voyages* de Champlain, p. 301: Paris, 1632. "Cultivent des champs dont ils tirent à suffisance pour leur nourriture de toute l' Année:" Relation da la Nouvelle France en l' année, 1636, p. 118. See also *Relation* en l' année, 1626, p. 2: Quebec, 1858. "The Hurons, more laborous, of more foresight, and more used to cultivate the earth, act with greater prudence, and by their labor are in a condition not only to subsist without any help, but also to feed others; but this, indeed, they will not do without some recompense:" Charlevoix, *Letters*, p. 175: London, 1763. "Evidences of their agricultural habits may still be traced in the large spaces which were cultivated, and which are yet conspicuous:" Schoolcraft, *Indian tribes of the United States*, vol. VI, p. 201. "Et continuent ainsi, jusques à ce qu' ils en ayent pour deux ou trois ans de provision, soit pour la crainte qu ' il ne leur succede quelque mauvaise année, ou bien pour l' aller traicter en d ' autres Nations pour des pelleteries ou autres choses qui leur font besoin:" Sagard, *Voyage des Hurons*, p. 134: Paris, 1632.

‖ *Voyage des Hurons:* Paris, 1632.

¶ "Leur coutume est, que chaque mesnage vit de ce qu' il pesche, chasse et seme ayans autant de terre comme il leur est necessaire; car toutes les forets, prairies et

use to-day by the white settlers on our frontiers, his account of it is translated in full. "The Indians," he says, "belt (coupent) the trees about 2 or 3 feet from the ground, then they trim off all the branches and burn them at the foot of the tree in order to kill it, and afterwards they take away the roots. This being done, the women carefully clean up the ground between the trees, and at every step they dig a round hole, in which they sow 9 or 10 grains of maiz, which they have first carefully selected and soaked for some days in water."*

Among the Iroquois or Six Nations, after they took up their residence in western New York, our accounts are not less full and explicit. Those grim warriors, thanks to the ill-advised interference of Champlain (A. D. 1609–'10), in their quarrel with the Adirondacks, lived in a chronic state of hostility to the French, whose pathway to the Ohio they effectually barred.† Expeditions were repeatedly fitted out against them, but always with the same barren results. A few villages were burned, sometimes by the savages themselves, to prevent their falling into the hands of the whites, and the adjacent corn-fields were destroyed; but the power of the confederacy remained unbroken. Champlain began this system of destructive inroads at an early period; in 1687 Denonville improved upon his teaching, and later on, in A. D. 1779, the Americans took up the work and showed themselves to be apt scholars. In this year Gen. Sullivan, at the head of an American army, invaded their country, and is said to have destroyed 160,000 bushels of corn, and to have cut down in one orchard alone 1,500 apple trees.‡ Large as was the amount of property destroyed at this time, it was but a fraction of the destruction wrought by the French under Denonville in 1687. In the course of that one invasion four villages of the Senecas were burned, and, including the corn in *cache* and what

terres non défrischees sont en commun, et est permis à un chacun d' en defrischer et ensemencer autant qu' il veut, qu' il peut et qu' il luy est necessaire; et cette terre ainsi defrischee demeure à la personne autant d' années qu' il continue de la cultiver et s' en servir, et estant entièrement abandonne du maistre s' en sert par apres qui veut et non autrement:" Sagard, *Voyage des Hurons*, p. 133: Paris, 1632. The Hurons agree among themselves "to allot each family a certain compass of ground, so that when they arrive at the place they divide themselves into tribes. Each hunter fixes his house in the center of that ground which is his district:" La Hontan, vol. II, p. 59: London, 1703.

* *Voyage des Hurons*, p. 134: Paris, 1632. Compare Adair, *History of the North American Indians*, p. 405: London, 1775. Smith, Virginia in Purchas' *Pilgrims*, vol. IV, p. 1696: London, 1625. *Voyages* de Champlain, pp. 73, 86: Paris, 1632.

† La Hontan, vol. I, p. 24: London, 1703. Loskiel, *Mission in America*, p. 137: London, 1794. Among the expeditions sent against them, besides those mentioned in the text, note particularly those in 1665 under Courcelles, in 1666 under de Tracy, in 1684 under de la Barre, and in 1692 and 1696 under Frontenac.

‡ *History of New York during the Revolutionary War*, vol. II, p. 334: New York, 1879. See, also, Stone's *Life of Brant*, vol. II, chap. i: Albany, 1865, for an account of the immense amount of corn, etc., destroyed at this time.

was standing in the fields, 400,000 minots or 12,00,000 bushels of grain were destoyed.* This amount is doubtlessly much exaggerated, but that it was very large is evident from the statements of Tonti† and La Hontan,‡ both of whom took part in the expedition. According to the former, they were for seven days engaged in cutting up the corn belonging to the four villages. The latter author puts the time consumed in this work at five or six days, and by way of showing the uselessness of such destruction, he makes one of their Indian allies remark rather cynically that "the Tsonnontonans did not matter the spoiling of the corn for that the other Iroquois nations were able to supply them." These extracts will give some idea of the extent to which corn was grown among these tribes,§ and will justify the use of much stronger language than Mr. Morgan employs when he declares that "it can not be affirmed with correctness that the Indian subsisted principally by the chase."‖

As to the manner of preserving or storing this grain for winter use, we are not left in the dark. In addition to the garrets or tops of their houses and cribs,¶ they were in the habit of "burying their surplus corn and also their charred green corn in *caches*, in which the former would preserve uninjured through the year, and the latter for a much longer period. They excavated a pit, made a bark bottom and sides, and having deposited the corn within it, a bark roof, water-tight, was constructed over it, and the whole covered up with earth."**

In regard to the field-work, the weight of evidence inclines to the conclusion that, ever since the arrival of the whites, it has been in the hands of the women and slaves, and that the warriors took no part in it, neither working the crop, nor clearing the land, as their congeners in

* Charlevoix, *Histoire de la Nouvelle France*, vol. II, p. 355: Paris, 1744. *Doc. Hist. of New York*, first series, p. 238: Albany, 1849.

† Narrative in *Historical Collections of Louisiana*, part I, p. 70.

‡ La Hontan, *Voyages*, vol. I, p. 77: London, 1703.

§ Iroquois "reap ordinarily in one harvest as much as serves 'em for two years:" Hennepin, *A new Discovery of a Vast Country in America*, vol. I, p. 18: London, 1698. "Cultivated 100 acres:" *Ibid.*, p. 19. "Corn plenty among different tribes of the Iroquois:" Greenhalgh (A. D. 1667), in *Doc. Hist. of New York*, vol. I, p. 15. "Corn has ever been the staple article of consumption among the Iroquois. They cultivated this plant, and also the bean and the squash, before the formation of the league. - - - Raised sufficient quantities of each to supply their utmost wants:" Morgan, *League of the Iroquois*, p. 199: Rochester, 1851. "Village field consisting oftentimes of several hundred acres of cultivated land:" *Ibid.*, p. 314.

‖ *League of the Iroquois*, p. 199: Rochester, 1851.

¶ Lafitau, vol. II, p. 80: Paris, 1724.

** *League of the Iroquois*, p. 319. Mr. Morgan adds that "pits of charred corn are still found near their ancient settlements. Cured venison and other meats were buried in the same manner, except that the bark repository was lined with deer skins." As to caches, see also Hennepin, *l. c.*, vol. I. p. 18: London, 1698. Lafitau, *Moeurs des Sauvages*, vol. II, p. 79: Paris, 1724. Loskiel, *Mission in America*, p. 68: London, 1794.

Canada were in the habit of doing. Colden* and others† assert this positively, and Gen. Ely S. Parker, himself an educated Iroquois, confirms the statement in an interesting letter which I take the liberty of publishing entire: "I do not think that the Iroquois men, at the time to which you refer, ever aided in any agricultural operations whatever. Among all the Indian tribes, especially the more powerful ones, the principle that a man should not demean himself or mar his dignity by cultivating the soil or gathering its product was most strongly inculcated and enforced. It was taught that a man's province was war, hunting, and fishing. While the pursuit of agriculture, in any of its branches, was by no means prohibited, yet, when any man, excepting the cripples, old men, and those disabled in war or hunting, chose to till the earth, he was at once ostracised from men's society, classed as a woman or squaw, and was disqualified from sitting or speaking in the councils of his people until he had redeemed himself by becoming a skillful warrior or a successful hunter. At the present day even, some of the western tribes require that one shall also prove himself an expert thief or robber to entitle him to respect and consideration. It is within my recollection that a very large proportion of the Iroquois men did no manual labor whatsoever, because as they argued it was menial and beneath their dignity. It is only quite recently that agricultural work by men has become general among this people, and not yet are women driven altogether from the field.

"It was an Iroquois custom to use captives to assist their women in the labors of the field, in carrying burdens, and in doing general menial labor; but when a captive proved himself possessed of what, in their judgment, constituted manly qualities, then he was fully adopted and admitted to all the privileges of an Iroquois.

"You may possibly call to mind that Brant, the elder, a great Iroquois warrior, and Red Jacket, the Iroquois orator, were not good friends. One was renowned both in war and council, and his voice was ever for war; while the other was famous only in council; his voice was always for peace, and in no sense was he a warrior. In a general council of the magnates of the Six Nations, held at the time of the Miami difficulties in the Northwest, Brant, in a controversy with Red Jacket, in which, perhaps, he was being worsted, taunted him with being a coward and a squaw, showing how strong had been his early education respecting the qualities essential to a representative Iroquois.

"I think you will also find accounts in Colden's History of the Five

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* "The Indian women perform all the drudgery about their houses; they plant the corn and labor it in every respect till it is brought to the table." *History of the Five Nations*, p. 13: London, 1747.

† "Women never plant corn among us as they do among the Iroquois:" Lawson, *Carolina*, p. 188: London, 1718. "The wife must do all the work in the house and field:" Loskiel, *Mission in America*, p. 60: London, 1794. See also *League of the Iroquois*, p. 329: Rochester, 1851.

Nations, where tribes of Indians were, or had been, subjugated by the Iroquois, and reduced to the condition of women, and were formally prohibited from engaging in any warlike enterprises, and were enjoined to spend their time and energies in tilling the earth, and the Iroquois were accustomed to express themselves respecting such subjugated tribes like this: 'We have put petticoats upon them,' which meant that thereafter they were required to do only servile work. This in my opinion was another evidence that anciently the Iroquois men did not do any agricultural labor."

*Per contra*, Charlevoix* speaks of a tradition current among them, to the effect that, formerly—before their arrival in New York—they were almost exclusively occupied in husbandry, and were bound to furnish a part of their harvest to the Algonquins, who in their turn agreed to supply them with a certain share of the products of the chase, and to defend them against all enemies whatsoever. He adds that this arrangement was very advantageous to both parties, but that in the estimation of the Indians it caused the Algonquins to rank higher than the Iroquois, for the reason that among them a successful hunter is on a level with a great warrior, and inferentially both take precedence of a husbandman. This however is but tradition, and is given for what it is worth, though it is proper to say that Charlevoix introduces it with the remark that it is the only part of Iroquois history that has come down to us clothed with any appearance of probability, and that both Colden† and Morgan‡ give place to the story. Without stopping now to inquire into its truth or falsity, we may be very sure that during the whole of the seventeenth and part of the eighteenth centuries, the Iroquois warrior had but little time to devote to agriculture. What with fighting the French and Hurons on the north; the Miamis and Illinois on the west; the Cherokees, Catawbas, and Shawnees on the south, to say nothing of his immediate neighbors in New England on the east, it would seem as if his hands were so full as to leave but little time for hunting, much less for raising corn; and that under the circumstances

*Charlevoix *Letters*, pp. 124, *et seq.*: London, 1763. La Potherie tells the same story, but gives it as a fact. See *Historie de l'Amerique*, vol. I, pp. 188, *et seq.*: Paris, 1753. The same author, vol. III, p. 18, asserts that the men did clear the ground, fence in the fields, and prepare the bunches of corn for drying. He also adds that when husband and wife are much attached to each other, they do not separate their work, though ordinarily they do not concern themselves about each other's duties. Lafitau, vol. II, p. 78, says that the men braided the corn into bunches, and adds that it is the only occasion on which the women call on the men for help.

†"The Adirondacks - - - employed themselves wholly in hunting, and the Five Nations made planting of corn their business. By this means they became useful to each other by exchanging corn for venison. The Adirondacks, however, valued themselves as delighting in a more manly employment, and despising the Five Nations in following business which they thought only fit for women." *History of the Five Nations*, p. 22: London, 1747.

‡ "Tradition informs us that, prior to the occupation of New York, they resided in the vicinity of Montreal, upon the northern bank of the St. Lawrence, where

"the plantation work," as the old chronicler has it, must have been "left to the women and slaves" as a matter of necessity.*

As might have been expected in a people who had developed such capacity for the management of military and political affairs, we find that the ideas of property had taken definite shape, and that the rights of individuals were duly respected. In fact, some of their regulations, notably those in relation to the property of married women,† might be copied with advantage in some of the States of our favored Republic. In regard to the tenure of land, we are told that no individual could obtain an absolute title, "but he could reduce unoccupied lands to cultivation to any extent he pleased; and so long as he continued to use them, his right to their enjoyment was protected and secured. He could also sell his improvements or bequeath them to his wife and children.‡

Turning now to the tribes of the Algonquin family, and beginning with those that lived south of the St. Lawrence and east of the Hudson, we can not but be struck with the similarity of their condition to that which, as we have seen, existed among the Hurons. Champlain,§ who visited this coast in the early part of the seventeenth century, found corn in cultivation from the "Kinnebequy" to Cape Mallebarre, near the southeastern extremity of Cape Cod. At Chacouet (Saco) he saw the natives cultivating the ground, "which was a thing he had not seen before, using for that purpose small implements of hard wood made like a spade." In the neighborhood of Cape Mallebarre they are said to have been very industrious ("fort amateurs du labourage") and to have provided a supply of corn for winter use, which they stored in caches.‖ They lived in stockaded forts,¶ and made slaves of their pris-

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they lived in subjection to the Adirondacks, a branch of the Algonquin race." *League of the Iroquois*, p. 5: Rochester, 1851. Compare this with the following statement of Father Le Jeune in *relation de la Nouvelle France* en l'année, 1636, p. 46: "Les sauvages m'ont monstré quelques endroits où les Hiroquois ont autrefois cultivé la terre."

* Lawson, *Carolina*, p. 188: London, 1718.

† "The rights of property, of both husband and wife, were continued distinct during the existence of the marriage relation, the wife holding and controlling her own the same as her husband, and in case of separation taking it with her. - - - If the wife either before or after marriage inherited orchards, or planting lots, or reduced land to cultivation, she could dispose of them at her pleasure, and in case of her death, they were inherited, together with her other effects, by her children." Morgan, *League of the Iroquois*, p. 326; Rochester, 1851. Schoolcraft, *Notes on the Iroquois*, p. 88, New York, 1846. La Potherie, vol. III, pp. 33, *et seq.*, Paris, 1753.

‡ *League of the Iroquois*, p. 326, Rochester, 1851.

§ *Voyages* de Champlain, chapters iv, v, vi, and vii, Paris, 1632. Compare Lescarbot, *Nouvelle France*, pp. 777-834-836, Paris, 1712. Also, *Relation de la Nouvelle France* en l'année, 1611-1613, Quebec, 1858.

‖ *Voyages* de Champlain, p. 90, Paris, 1632.

¶ De Laet in *New York Hist. Coll.*, first series, vol. I, p. 307. Champlain, p. 74: Paris, 1632. Lescarbot, book V, p. 632, Paris, 1712. Williams, Key to the Indian Language, in vol. I, *Rhode Island Hist. Coll.*, p. 92. Vincent, Pequot War in *Massachusetts Hist. Coll.*, vol. VI of third series, p. 39. Purchas, *Pilgrims*, vol. IV, p. 1844, London, 1625.

oners, especially of the women and children,* as was the custom among other tribes belonging to this family.† In 1614 Capt. Smith explored this coast, and makes mention of "the gardens and cornfields which he saw planted on those sandy cliffs and cliffs of rocks."‡ He also bears witness to the quantities of corn grown in that region when he undertakes for a few trifles, "to have enough from the salvages for three hundred men" until the colony should become self-supporting.§ Roger Williams, A. D. 1643, on the same subject says "that the women of the family commonly raise two or three heaps of 12, 15, or 20 bushels a heap, - - - and if she have the help of her children or friends, as much more." He also adds, that "sometimes the man himself (either out of love to his wife or care for his children, or being an old man) will help the women, which, by the customs of the country, they are not bound to. When a field is to be broken up they have a very loving, sociable, speedy way to dispatch it; all the neighbors, men and women, forty, fifty, a hundred, do joyne and come in to help freely. With friendly joyning they break up their fields and build their forts."‖ Among themselves they bartered their corn, skins, and venison,¶ and they also carried on more or less trade with other nations in shell beads** (wampum), and also in pipes, which latter article is said usually "to come from the Mauquawwop†† or man-eaters, three or four hundred miles from us." The right of property was recognized in land,‡‡ and their fields as well as the district within which each man might hunt were

* Lescarbot, *Nouvelle France*, book VI, pp. 798 and 859, Paris, 1712.

† Lafitau, *Moeurs des Sauvages Ameriquains*, vol. I, p. 563, and vol. II, p. 308, Paris, 1724. Lawson, *Carolina*, pp. 198–232, London, 1718. Marquette in *Discovery and Exploration of the Mississippi*, by John G. Shea, p. 32, New York, 1852. Charlevoix, *Histoire de la Nouvelle France*, vol. IV, pp. 104, 105, and p. 156, where the Outagamis, as a condition of peace, propose to replace all the killed of their enemies by slaves whom they are to capture from distant nations: Paris, 1744.

‡ Description of New England in *Collections of Mass. Hist. Society*, vol. VI of third series, p. 180.

§ *Ibid.*, p. 113.

‖ Williams, Key, pp. 92 and 93. "Their food is pulse, - - - which is here better than elsewhere, and more carefully cultivated," Verrezano, in *N. Y. Hist. Coll.*, vol. I of new series, p. 49. "Their food is generally boiled maize or Indian corn," Gookin, History of the New England Indians in *Coll. Mass. Hist. Soc.*, vol. I of first series, p. 150. "Taking all his" (King Philip's) "cattle and hogs that they could find, and also took possession of Mount Hope, which had then a thousand acres under corn." Drake, *Indians of North America*, p. 209, fifteenth edition. "Indians came down to Windsor and Hartford with fifty canoes, at one time, laden with Indian corn;" Trumbull, *Connecticut*, vol. I, p. 88, Hartford, 1797. On Block Island, Indians had "about 200 acres of corn," Drake, *Indians of North America*, p. 116. See also Winslow, Good News from New England, in Purchas *Pilgrims*, London, 1625.

¶ Williams, Key to the Indian Language, in vol. I *Coll. Rhode Island Hist. Soc.*, p. 133.

** Lafitau, *Moeurs des Sauvages Ameriquains*, vol. 1, p. 503, Paris, 1724.

†† Probably Mohawk. See Drake, *Indians of North America*, p. 221, fifteenth edition.

‡‡ I have known them to make bargaine and sale amongst themselves for a small piece or quantity of land." Williams, Key, p. 89.

clearly defined.* They also seem to have arrived at that stage of development in which the advantages of a division of labor are recognized, for we are told that "they have some who follow only making of Bowes, some Arrows, some Dishes (and the women make all their earthen vessels); some follow fishing, some hunting: most on the seaside make money," *i. e.*, wampum. "As many make it as will."†

Among the tribes living in southeastern New York, and along the Hudson, there does not seem to have been any lack of corn. Hudson, A. D. 1609, states that in latitude 42° 18′, near where the town bearing his name now stands, he saw "a house which contained a great quantity of maize or Indian corn and beans of last year's growth, and there lay near the house for the purpose of drying enough to load three ships, besides what was growing in the fields."‡

The work of tilling the ground was left to the women, who had the assistance of the old men and the children.§ The warriors are said to have been extravagantly inclined to hunting and fishing,‖ though DeLaet tells us that "they are very serviceable, and allow themselves to be employed in many things for quite a small compensation.¶ They lived in stockaded villages, and had forts or castles near their corn grounds for refuge in case of the sudden irruption of small marauding parties of their enemies."**

New Jersey and eastern Pennsylvania were inhabited, in part, by different bands of the same tribes that held the country adjacent to the mouth of the Hudson. They occupied both banks of the Delaware or "South" river, lived in forts,†† and raised corn and beans, which they sold to the Swedish and German settlers.‡‡ Later, about the year 1682,

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* "They have their fields distinct:" Lescarbot livre VI. pp. 776, 836: Paris, 1712. Williams, Key, p. 141. Winslow, in Purchas *Pilgrims*, p. 1869: London, 1625.

† Williams, Key, pp. 128 and 133.

‡ Quoted in DeLaet, *Description of New Netherlands*, p. 300. "Great store of Maize:" Juet, *Journal of Hudson's Voyage*, p. 323. "They raise an abundance of corn and beans, of which we obtain whole cargoes in sloops and galleys in trade:" Vander Donck, *New Netherlands*, p. 209. "Their common food - - - is *pap*, or *mush*, which - - - is named *sapaen*. This is so common among the Indians that they seldom pass a day without it, unless they are on a journey or hunting. We seldom visit an Indian lodge at any time of day, without seeing their *sapaen* preparing, or seeing them eating the same. It is the common food of all:" *Ibid.*, p. 193. All these are published in vol. I, new series, of the *Collections of the New York Hist. Society*, and the paging refers to that volume. "Indian corn abundant:" *Doc. Hist. of New York*, p. 22.

§ Vander Donck, *New Netherlands*, in vol. I, new series, *Hist. Coll. of New York*, p. 208.

‖ *Ibid.*, p. 209.

¶ DeLaet, *Description of New Netherlands*, in vol. I, new series, *Coll. N. Y. Hist. Soc.*, p. 301, New York, 1841.

** Vander Donck, *l. c.*, p. 197.

†† DeLaet, *l. c.*, p. 303.

‡‡ Kalm, *Travels*, vol. I, p. 397: London, 1772. Campanius, History of New Sweedland in vol. I, *Coll. of New York Hist. Soc.*, p. 346. De Vries Voyages in Vol. I, new series, of *Coll. of New York Hist. Soc.*, p. 253.

William Penn found the Delawares and Shawnees* still occupying this region, and it was with them that he concluded the famous treaty of which it has been said that it is the only one ever made that was not ratified by an oath, and that it is the only one that was never broken. Speaking of their manner of life, he says that "their diet is maize or Indian corn, divers ways prepared; sometimes roasted in the ashes, sometimes beaten and boiled with water, which they call hominy."† Loskiel, A. D. 1788, takes up the story, and tells us that corn was the chief product of their plantations.‡ He also says that "the men hunt and fish and provide meat for the household, keep their wives and children in clothing, build and repair the houses or huts, and make fences around the plantations, occasionally assisting in the labors of the field and garden.§ The corn is stowed in caches, and they keep the situation of these caches secret, as if found out they would have to supply every needy neighbor." This, he adds, "may occasion a famine, for some are so lazy that they will not plant at all, knowing that the more industrious can not refuse to divide their store with them."‖ They also did more or less barter, especially in pipes, the material for which, a red marble, is rare, and found only on the Mississippi. "A more common sort is made of a kind of ruddle dug by the Indians living to the west of the Mississippi, on the Marble River, who sometimes bring it to these countries for sale."¶

At this point it seems proper to refer briefly to the fact noticed by Gen. Parker, that the Delawares were, at this time, a conquered tribe, and held their lands on sufferance. In the figurative language of the Indians, the Iroquois had put petticoats on them. Whether this was a rhetorical flourish, and merely meant that they had been conquered, or whether it was intended to signify that the Delaware warriors had been forbidden to take part in manly pursuits, and were restricted to the occupations usually followed by the women, I am not prepared to say. That they were forbidden to dispose of the land they occupied is clear from the speech of Canassatego, an Iroquois sachem, at the treaty of Lancaster, A. D. 1744;** but, on the other hand, it is equally evident

* Harvey, *History of the Shawnee Indians*, p. 1: Cincinnati, 1855. This tribe is, said to have been the custodian or keeper of the parchment copy of the great treaty of 1682. At least they had it in 1722, and showed it to Gov. Keith: *Hist. of Shawnees*, p. 32. Parkman, in *Conspiracy of Pontiac*, vol. II, p. 229, says: "They had parchment copies of treaties with Penn."

† Penn's letter quoted in Harvey's *History of the Shawnee Indians*, p. 14: Cincinnati, 1855.

‡ Loskiel, *Mission of the United Brethren among the Indians of North America*, p. 66: London, 1794.

§ *Ibid.*, p. 59.

‖ *Ibid.*, p, 68.

¶ *Ibid.*, p. 51. Compare Kalm, *Travels*, vol. II, p. 42.

** "We conquered you; we made women of you; you know you are women, and can no more sell land than women." Colden, *History of the Five Nations*, vol. II, p. 80: London, 1767. See also Speech of John Hudson, the Cayuga Chief, A. D., 1758.

that the Delaware warrior did not hesitate to go upon the warpath whenever it suited his pleasure to do so.* Probably the true explanation of this seeming inconsistency is to be found in the fact that whilst the Delawares, as a tribe, were prohibited from exercising any of the rights of an independent people, yet the individual warrior, in the enjoyment of that wide personal liberty to which every Indian east of the Mississippi seems to have been born, consulted his own convenience as to when or with whom he should fight, and when or how, if at all, he should aid the women in the work of cultivating the fields.

In Virginia, among the tribes composing the Powhatanic confederacy and the adjoining nations, corn was raised in great abundance, though there were times when, owing to improvidence or a failure of the crops, the Indians suffered more or less from want. Capt. Smith, in the course of one of the many expeditions made in order to supply the starving colonists with food, says that he could have loaded a ship with it;† and in his letter to the Queen on the occasion of the visit of the "Lady" Pocahontas to England, after acknowledging his personal obligations to that "tender virgin," he tells us that for two or three years "shee, next under God, was still the instrument to preserve this colonie from deathe, famine, and utter confusion."‡ We are also told that they had stockaded forts,§ and that their houses were built in the midst of their fields or gardens, "which are small plots of ground," ranging from 20 to 200 acres.|| Each household is said "to know their own lands and gardens, and must live of their own labors;"¶ and the limits within

at a conference held at Burlington, in Archæologia Americana, vol. II, p. 48. In this connection, and as showing the similiarity of customs among the Indians, it is of interest to note that the Creeks claimed to have put petticoats upon the Cherokees, and at the treaty of Augusta, in reply to the statement of the Georgians "that they had bought a certain piece of land from the Cherokees," a Creek chief started to his feet, "and, with an agitated and terrific countenance, frowning menaces and disdain, fixed his eyes on the Cherokee chiefs and asked them what right they had to give away their lands, calling them old women, and saying that they had long ago obliged them to wear the petticoat." Bartram, *Travels through Florida*, p. 486: Philadelphia, 1791.

* Heckewelder, *Historical account of the Indian Nations*, including the Introduction, where this subject is discussed at length from the point of view of the Delawares.

†Capt. Smith, *News from Virginia*, p. 20 of the reprint by Charles Dean, Esq.: Cambridge, 1866.

‡Smith, *Virginia*, p. 121: London, 1632. "It pleased God, after awhile, to send these people - - - to relieve us with victuals, as Bread, Corne, Fish, and Flesh in great plenty, which was the setting up of our feeble men, otherwise we all had perished. Also we were frequented by divers Kings in the Countrie, bringing us store of provision to our great comfort." Master Geo. Percy, in Purchas *Pilgrims*, vol. IV, p. 1690: London, 1625.

§Capt. Smith, in Purchas *Pilgrims*, vol. IV, pp. 1693–4: London, 1625. Beverly, Virginia, book III, p. 12: London, 1705. Hariot in Hakluyt, *Voyages*, vol. III, p. 329: London, 1810.

||Smith, in Purchas *Pilgrims*, vol. IV, p. 1698: London, 1625.

¶ *Ibid.*, p. 1698.

which each might "fish, fowle, or hunt" seem to have been not less accurately determined.* As to the part taken by the men in the field work, our authorities are not agreed. According to Capt. Smith, who is not very clear upon this point, the women plant and gather the corn,† though elsewhere he speaks of the "King (Powhatan) himself making his own robes, shoes, bowes, arrows, pots, planting, also hunting, and doing offices no less than the rest." His account of the manner of making a "clearing" is also somewhat obscure, and may be interpreted to mean that this part of the labor was performed by the men. Be this as it may, however, other writers are more explicit. Hariot and Beverly confirm what is said as to the supply of corn; and the former asserts directly, and the latter by implication, that the men did take part in the field work.‡ They also did, more or less, trade among themselves, exchanging, among other things, their "countrie corne" for copper, beads, and such like.§ Slavery may also be confidently said to have existed among them; for, although the evidence on this point is not as full and clear as it might be, yet the fact is plainly deducible from the statement that "they made war, not for lands or goods, but for women and children, whom they put not to death," but kept as captives, in which capacity they were made "to do service."‖

The Carolinas were held by a number of tribes belonging to different linguistic families, though with but little or no difference in their manners and customs. The Tuscaroras, a Huron tribe, occupied the country adjacent to the Chowan River and its tributaries, in the western part of North Carolina, until about the year 1713–'15, when, owing to their defeat by the whites, and the destruction of their fort, they fled to the north, and took refuge among the Iroquois, forming the sixth nation in that confederacy.¶ In the western part of South Carolina lived the Catawbas, who are chiefly known on account of the long

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*Capt. Smith, in Purchas' *Pilgrims*, vol. IV, p. 1703.

†*Ibid.*, pp. 1698, 1709 (vol. IV).

‡"All the aforesaid commodities" (corn, beans, peaze, etc.) "for victual are set or sowed some time in grounds apart and severally by themselves, but for the most part mixtly. - - - A few days before they sowe or set, the men with wooden instruments, made almost in form of mattocks, or hoes with long handles; the women with short pickers or parers, because they use them sitting, of a foot long, and about 5 inches in breadth, doe only break the upper part of the ground to raise up the weeds, grasse, and old stubs of corn-stalks with their roots." Hariot in Hakluyt, *Voyages*, vol. III, p. 329: London, 1810. "Indian corn was the staff of Food upon which the Indians did ever depend. - - - It was the families dependance, and the support of their women and children." Beverly, *Virginia*, part II, p. 29: London, 1705. At their corn feast they boast in their songs "that their corne being now gathered, they have store enough for their women and children; and have nothing to do but go to war, travel, and seek out new adventures." *Ibid*, part III, p. 43.

§Capt. Smith, in Purchas *Pilgrims*, vol. IV, p. 1701: London, 1625.

‖ *Ibid.*, *l. c.*, pp. 1699, 1700. "The werowance, women and children, became his prisoners, and doe him service." *Ibid.*, p. 1704.

¶ *Archæologia Americana*, vol. II, p. 80, *et seq.*

and relentless war which they waged against the Iroquois. They were extensively engaged in growing corn, as Adair speaks of one of their old fields that was 7 miles in extent, and argues that the tribe must have been very populous to cultivate so much land with their dull stone axes.* In the interior, and along the coast of these two States, there dwelt a number of small tribes, whose names have scarcely come down to us. In 1700–'01 Lawson travelled through this region, and much that we know of the people who then lived here is derived from his narrative. From it, we learn that they cultivated many kinds of pulse, part of which they ate green in summer, keeping great quantities for their winter supply.† This they stored in cribs or granaries, which were sometimes built on 8 feet or posts, about 7 feet high, well daubed within and without with loam.‡ The young men worked the fields, as did the slaves, who, we are told, were not overworked.§ The women never planted corn as they did among the Iroquois.|| There were no fences to divide the fields, but "every man knew his own; and it scarce ever happens that they rob one another of so much as an ear of corn, which if anyone is found to do, he is sentenced by the elders to work and plant for him that was robbed till he is recompensed for all the damage he has suffered in his cornfield; and this is punctually performed, and the thief held in disgrace that steals from any of his country-folks."¶ In the case of a woman without a husband, and with a great many children to maintain, the young men were obliged to plant and reap and do everything that she was not capable of doing herself. They do not allow any one to be idle, but all must employ themselves in some work or other.¶ They bartered pipes, wooden bowls, and ladles with neighboring tribes for raw skins.** We are also told that the poorer sort of white planters often got them to plant, by hiring them for that season, or for so much work.††

Of the tribes that inhabited Florida, including under that title Georgia, Tennessee, Arkansas, and all the Gulf States except Texas, our accounts are very full and explicit. From the time of De Soto, A. D. 1539, and even earlier,‡‡ corn was grown everywhere in great abundance. Indeed, but for the quantities seized by that adventurer during the three or four years he passed in rambling, to and fro, over the vast region traversed by him on both sides of the Mississippi, he

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*Adair, *History of the American Indians*, p. 225: London, 1775.

†Lawson, *Carolina*, p. 207: London, 1718.

‡*Ibid.*, pp. 17 and 177.

§*Ibid.*, pp. 179, 232, 198.

||*Ibid.*, p. 188.

¶*Ibid.*, p. 179.

***Ibid.*, pp. 58, 176, 208.

††*Ibid.*, p. 86.

‡‡Cabeca de Vaca, in Buckingham Smith's translation, pp. 41–47: New York, 1871. Herrera, *History of America*, vol. VI, pp. 30, 31: London, 1740.

could not have subsisted his horde of ruthless followers, with their attendant trains of captives and domestic animals.* La Vega, Biedma, and above all the Knight of Elvas, bear witness to this fact on almost every page of their narratives.† We are also told that, on both sides of the river, the natives lived in walled towns,‡ and that they gathered every man his own crop,§ which they stored in barbacoas‖ or granaries, made somewhat like those in Carolina.

Passing over an interval of a hundred and fifty or two hundred years, and coming down to the eighteenth century, we find the condition of affairs in all that region practically unchanged. The same tribes, with scarcely an exception, that held the country east of the Mississippi in the time of De Soto still possessed it, and lived substantially within the same boundaries as they did when first visited. In the meantime, the Mississippi had been explored from the Falls of St. Anthony to its mouth, the French and English had pushed their trading posts everywhere throughout the valley, and were contending for the possession of all that vast domain; but the Indians, save when brought into immediate contact with the whites, still pursued the even tenor of their way, and hunted and fought, danced and worshiped, much as their ancestors had done some two hundred years before. They built their houses and fortified their villages in much the same manner,¶ and cultivated their fields and gardens with the same rude and unsatisfac-

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* "We landed six hundred and twenty men and two hundred and twenty-three horses." Narrative of Biedma, in *Hist. Coll. of Louisiana*, part II, p. 97. This is the smallest number given by either one of the chroniclers of this expedition, and it is accepted for this reason. It will be seen that no mention is made of the drove of hogs, though it must have been large, as we are told, *l. c.*, p. 104, that in the attack made by the Indians on the Spaniards when in winter quarters at Chicaça, they destroyed "three hundred hogs," besides fifty-seven horses. The Gentleman of Elvas says "fifty horses and four hundred hogs."

† "In the barns and in the fields great store of maize. - - - Many sown fields which reached from one (town) to the other," p. 152. "In the town was great store of old maize, and great quantities of new in the fields," p. 172. - - - "The maize that was in the other town was brought hither; and in all it was esteemed to be six thousand *harneys* or bushels," p. 203. - - - "As soon as they came to Cale, the governor commanded them to gather all the maize that was ripe in the fields, which was sufficient for three months," p. 130: Narrative of the expedition of Hernando de Soto, by a Gentleman of Elvas, in *Hist. Coll. of Louisiana*, part II. "De Soto did not kill any of his hogs, because they found plenty of provisions:" Herrera, vol. V, p. 312: London, 1740. "Caciquess" of Cofachiqui "had 2,000 bushels of maize in one of her towns:" *Ibid.*, p. 317.

‡ Gentleman of Elvas and Biedma, in *Hist. Coll. of Louisiana*, part II, pp. 103, 104, 160, 172: Philadelphia, 1850. Garcilasso de la Vega, seconde partie, pp. 19–37: Paris, 1709.

§ A brief note, - - - taken out of the 44th chapter of the *Discovery of the Inland of Florida* on the backside of Virginia, begun by Fernando de Soto, A. D. 1539, in Mass. Hist. Coll., Vol. VIII, third series, p. 115.

‖ Gentleman of Elvas, *l. c.*, p. 137.

¶ Du Pratz, *History of Louisiana*, vol. II, p. 251: London, 1763. Dumont, Memoir in Hist. Coll. of Louisiana, part V, p. 108: New York, 1853.

tory implements. * In all this they did not differ from their neighbors to the North; in fact, so similar were their forms of government, their customs, and their religious beliefs, that, *mutatis mutandis*, the accounts given of the Hurons and Algonquins might, with but little change, be applied to the tribes living south of the Ohio.† In one or two particulars, however, there seems to have been some improvement, notably in their organized system of relief for the poor and needy, which seems to have existed from the earliest period,‡ and in the provision, made at harvest time for the exercise of tribal hospitality, and for defraying, what may be justly termed, public expenditures.§ In their method, too, of preventing, or rather, punishing laziness, which they did by fine,|| they showed an advance in social science that is worthy of all commendation. Among them corn was the staple article of food,¶ and was cultivated in great quantities, their fields not unfrequently being measured by *miles* instead of by *acres*.** The work was done in common, though the fields were divided by proper marks, and the harvest was gathered by each family separately.†† The men are said to have

* See *ante*, foot-note †, on page 509.

†Lafitau, *Moeurs des Sauvages Ameriquains*, vol. I, p. 530: Paris, 1724.

‡"Caciquese of Cofachiqui had two storehouses for the relief of the needy:" Herrera, vol. v, p. 316: London, 1740. Timberlake, who visited the Cherokees, A. D. 1761, and accompanied a delegation of them to England, describes their method of relieving the poor, which resembles, in some respects, the "begging dance" of the Indians of the Plains: *Memoirs*, p. 68: London, 1765.

§ "Previous to their carrying off their crops from the field, there is a large crib or granary, erected in the plantation, which is called the King's crib; and to this each family carries and deposits a certain quantity, according to his ability or inclination, or none at all if he so chooses; this in apearance seems a tribute or revenue to the mico, but in fact is designed for another purpose, *i. e.*, that of a public treasury, supplied by a few and voluntary contributions, and to which every citizen has the right of a free and equal access, when his own private stores are consumed, to serve as a surplus to fly to for succor, to assist neighboring towns, whose crops may have failed, accommodate strangers or travelers, afford provisions or supplies when they go forth on hostile expeditions, and for all other exigencies of the State:" Bartram, *Travels through Florida*, p. 512: London, 1791. The Huron-Iroquois also had a public treasury, which contained wampum, Indian corn, slaves, fresh and dried meat, and, in fact, anything else that might serve to defray the public expenses. See Lafitau, vol. I, p. 508, and vol. II, p. 273.

|| "The delinquent is assessed more or less, according to his neglect, by proper officers appointed to collect those assessments, which they strictly fulfill without the least interruption or exemption of any able person:" Adair, *History of American Indians*, p. 430: London, 1763. Compare Lawson, *Carolina*, p. 179: London, 1718.

¶ "Chief produce and main dependence:" Adair, p. 407. "Principal subsistence:" Du Pratz, *History of Louisiana*, vol. II, p. 239: London, 1763. "Common food of the Creeks is Indian corn:" Schoolcraft, *Indian Tribes*, vol. v, p. 264. "They sow their maize twice a year:" Laudonnière, in *Hist. Coll. of Louisiana*, part p. 174.

** Adair, pp. 225, 353, 411: London, 1763. Bartram, *Travels through Florida*, pp. 54, 332, 350, 352, 354: Philadelphia, 1791. Narrative of Joutel, in Margry, vol. III, p. 462: Paris.

†† Bartram, p. 512. Adair, p. 430. Romans, *East and West Florida*, p. 87.

aided in the field-work. Indeed, so general was this custom, that I do not know of a single prominent tribe living east of the Mississippi and within the limits named, in which this can not be shown to have been the case.* The Choctaws, as we have seen, were a nation of farmers, and helped their wives in the labors of the field and in many other kinds of work;† the Muscogees rarely went to war until they had helped the women to plant a sufficient plenty of provisions,‡ and Hawkins tells us that to constitute a legal marriage among them, a man must, among other things, "build a house, make his crop, and gather it in, then make his hunt, and bring home the meat;" and that when all this was put in possession of the wife, the ceremony was ended, or as the Indians express it "the woman was bound, and not till then."§

Among the Natchez and kindred tribes, the men not only cleared the fields and worked the crops,‖ but in one field, that in which was raised the corn destined for use in the feast of the "Busk" or First Fruits, the ground was prepared and cultivated by the warriors alone, and the women were not allowed to take any part in the work at any stage.¶ Slavery was common among all these nations from the earlies times, as it was also among tribes belonging to the Huron and Algonquin families of the North, that being the usual lot of the captives, especially of the women and children. In the time of De Soto we are told that some of these tribes had many "foreign Indian slaves, taken in war, whom they put to tilling the ground and other sorts of labor; and that they might not run away, they used to cut their heels, or some sinews in their legs, so that they were all lame."** At a later time, the custom of enslaving captives still existed,†† though I do not find that they were mutilated in order to prevent their escape. It is quite probable however that this was still sometimes done, as Lawson

* Laudonnière, *l. c.*, p. 174. Bartram, pp. 194, 226, 512. Adair, pp. 407–430. Romans, p. 85. Memoir of Tonti, in *Hist. Coll. of Louisiana*, vol. I, p. 63 Le Moyne, plate xxi: Frankfort ad Moenum, 1591.

† Bernard Romans, *East and West Florida*, pp. 71, 83, 85: London.

‡ Adair, *History of American Indians*, p. 255: London, 1775.

§ Sketch of the Creek Country, in *Collections Georgia Hist. Soc.*, p. 42. Schoolcraft, *Indian Tribes of the United States*, vol. V., p. 267.

‖ Du Pratz, *Hist. of Louisiana*, vol. II, pp. 168–189: London, 1763. Among the Tonicas on west side of the Mississippi, "the men do what peasants do in France; they cultivate and dig the earth, plant and harvest the crops, cut the wood and bring it to the cabin," etc. Father Gravier, in Shea's *Early Voyages*, p. 134: Albany, 1861. Compare St. Cosme in same, p. 81.

¶ Du Pratz, vol. II, p. 189.

** Herrera, *History of America*, vol. V, p. 320: London, 1740.

†† M. Penicaut, in *Hist. Coll. of Louisiana*, new series, pp. 123, 124: New York, 1869. Brinton, *Floridian Peninsula*, p. 141: Philadelphia, 1859. Bartram, *Travels through Florida*, pp. 186, 213, 507. Narrative of La Salle's voyage down the Mississippi by Father Membré, in *Discovery and Exploration of the Mississippi*, p. 171: New York, 1852. Du Pratz, *Louisiana*, vol. II, p. 249. Schoolcraft, *Indian Tribes*, vol. V, p. 260. Timberlake, *Memories relating to the Cherokees*, p. 90: London, 1765. Herrera, vol. VI, p, 260: London, 1740.

speaks of an Indian captive who had been thus treated by the Senecas, but who had nevertheless managed to escape and find his way back to North Carolina in that crippled condition.* These nations excelled in manufactures, such as pipes, pottery, and wickerwork,† and seem always to have had more or less traffic among themselves.‡ Indeed, Herrera speaks of "merchants that travelled up the country," and the experience of Cabeça de Vaca among the Indians of Texas, as a dealer in flint and other articles, which he brought from the interior and bartered with the Indians of the coast, would seem to be decisive as to the existence among them of a class of pedlers.§

Of the tribes that lived on the west bank of the Mississippi, our accounts are not so full; but from what we do know of them, it is safe to say that in their manner of life they did not differ materially from their neighbors on the other side of the great river. In the time of La Salle, A. D. 1682, they lived in fixed villages ("sedentaires"),‖ as they had done some hundred and fifty years before, when De Soto swept through that country like a tornado, and they still cultivated corn in great abundance.¶ Peach, plum, and apple trees were found among the tribes living near the mouth of the Arkansas;** and these same tribes are said to have had great quantities of domestic fowls, including flocks of turkeys;†† in short, to have been "half-civilized."‡‡ As Joutel

* Lawson, *Carolina*, p. 53: London, 1718.

† Adair, p. 423: London, 1775. Du Pratz, *Louisiana*, book IV, chap. iii, sec. 5: London, 1763.

‡ Herrera, vol. v, p. 310: London, 1740. Laudonnière in Hakluyt's *Voyages*, vol. III, p. 369: London, 1810. Schoolcraft, *Indian Tribes of the United States*, vol. v, p. 692.

§ "With my merchandise and trade I went into the interior as far as I pleased, and travelled along the coast 40 or 50 leagues. The principal wares were cones and other pieces of sea snail, conches used for cutting, and fruit like a bean, of the highest value among them, which they use as a medicine, and employ in their dances and festivities. Among other matters were sea beads. Such were what I carried into the interior; and in barter I got and brought back skins, ochre, with which they rub and color the fac, hard canes of which to make arrows, sinews, cement, and flint for the heads, and tassels of the hair of deer, that by dyeing they make red. This occupation suited me well; for the travel allowed me liberty to go where I wished. I was not obliged to work, and was not treated as a slave. Wherever I went I received fair treatment, and the Indians gave me to eat out of regard to my commodities." Relation of Cabeça de Vaca, translated by Buckingham Smith, pp. 85, *et seq.*: New York, 1871.

‖ Memoirs of the Sieur de Tonti, in *Hist. Coll. of Louisiana*, p. 64.

¶ Narratives of Fathers Marquette and Membre, in *Discovery and Exploration of the Mississippi*, pp. 48, 169, 177. Memoir of Tonti, and Joutel's Journal, both in *Hist. Coll. of Louisiana*, part I, pp. 63, 65, 151, 153, 163, etc. The latter author in Margry, vol. III, p. 462, Paris, tells us that the Kappas had a field a league in length by 1½ in width.

** Tonti, *l. c.*, p. 61.

†† Narrative of Father Membré, *l. c.*, p. 169.

‡‡ *Ibid.*, p. 172. "Nothing barbarous but the name." Narrative of Father Douay, in *Discovery and Exploration of the Mississippi*, p. 203.

tells us that there was but little difference in the religion, manners, clothing, and houses of the nations inhabiting this region,* it seems fair to conclude that the others were not behind the favored few in all that contributed to the physical comfort and well-being of a people. Their men cleared the ground, and aided in the work of the fields;† and among the Tensas, they had so far anticipated modern methods, that in one "clearing," called by them "the field of the spirit," they are said to have worked to the music of the drum.‡ The labor of the fields was done in common, though each family had its own particular plot of ground.§ The harvest was gathered separately by each family, and was stored in magazines, or in large baskets made of cane, or in gourds as large as half barrels.‖ In other respects, too, individual rights seem to have been respected.¶ Slavery existed among the Tensas and other tribes who are said to have had the same customs.** They had more or less traffic with other tribes, especially in bows, in the manufacture of which the Caddoes are said to have excelled.††

Ascending the Mississippi, we find among the Algonquin tribes of the Northwest a condition of affairs very similar to that which has been described as existing among their kindred and neighbors to the eastward. At the date of the arrival of the French, say in the beginning of the last quarter of the seventeenth century, the Miamis, Kickapoos, Winnebagoes, Outagamis or Foxes, and other tribes, were living in Wisconsin and the northern part of Illinois,‡‡ whilst all south of that, extending as far as the mouth of the Ohio, was held by the Illinois and their allies, among whom were a few villages of Shawnees. These latter came later, having established themselves here upon the invitation of La Salle,§§ though the home of their tribe is said to have been, at this time, some thirty days' journey to the east-southeast, in what is

*Joutel, *Journal, l. c.*, pp. 151, 152. Tonti, *l. c.*, pp. 62, 63.

†Tonti and Joutel, *l. c.*, pp. 63–149. Father Gravier, in Shea's *Early Voyages*, p. 134: Albany, 1861. "Men among Tonicas employed solely on their fields." St. Cosme, *l. c.*, p. 81.

‡Tonti, *l. c.*, p. 62. Adair, *l. c.*, p. 407, speaking of the Creeks, says that sometimes when at work in the fields, "one of their orators cheers them with jests and humorous old tales, and sings several of their most agreeable wild tunes, beating also with a stick in his right hand on the top of an earthen pot covered with a wet and well-stretched deerskin." Compare also Lawson, *Carolina*, p. 175: London, 1718.

§Joutel, *Journal, l. c.*, p. 149. Charlevoix, *Nouvelle France*, vol. III, pp. 21, 22.

‖*Memoir* of the Sieur de Tonti, *l. c.*, p. 61. *Narrative* of Father Marquette, p. 48.

¶In their cottages "they have nothing in common besides the fire." Joutel, p. 148.

***Narrative* of Father Membré, pp. 171–182. In his Memoir, Tonti, p. 61, speaks of the "maitre d'hotel" to the chief of the Tensas. See also Joutel, *Journal*, p. 160, and La Harpe in *Hist. Coll. of Louisiana*, part III, p. 68.

††Tonti, p. 73.

‡‡*Narrative* of Father Marquette, pp. 13–22.

§§*Memoir* of Tonti, p. 66. *Narrative* of Father Membré, *l. c.*, p. 163.

now known as the State of Kentucky,* where they seem to have taken refuge after their expulsion from the region south of the lakes by the Iriquois.† Among all these nations corn was cultivated in quantities, and was preserved in caches.‡ The field work seems to have been left to the women§ and slaves. There was also a class of boys or men who were employed only in women's work, and who did not take part either in war or hunting. It is possible that they were simply captives or slaves, though upon this point the evidence is conflicting.‖ It is cer-

* Life of Father Marquette, p. 56, and also p. 41 of his *Narrative*, both in Shea's *Discovery and Exploration of the Mississippi*. In the old maps, the Cumberland is put down as the river of the Chaouanons.

† Colden (*Five Nations*, pp. 23 and 25: London, 1767) says the Shawnees, or, as he calls them, the Satanas, formerly lived on the banks of the lakes, and that they were the first people against whom the Five Nations turned their arms, after their defeat and expulsion from the region near Montreal by the Adirondacks. There is reason to believe that this took place in the latter part of the sixteenth century.

‡ "The soil is good, producing much corn," p. 14. - - - "They live - - - on Indian corn, of which they always gather a good crop, so that they have never suffered by famine," p. 33 of *Narrative* of Marquette. "They live on Indian corn and other fruits of the earth, which they cultivate on the prairies like other Indians:" Narrative of Father Allouez, p. 75. "The richness of their country gives them fields everywhere:" *Narrative* of Father Membré, p. 151. All these are published in the *Discovery and Exploration of the Mississippi* by John Gilmary Shea: New York, 1852. "This is a place of great trade for skins and Indian corn, which these savages sell to the Coureurs dë Bois:" La Hontan, *Voyages* I, p. 105: London, 1703. See also *Memoir* of Tonti, *l. c.*, p. 54.

§ Joutel, p. 187. Kips, *Missions*, p. 38. Father Marest, in note to p. 25 of Shea's *Discovery and Exploration of the Mississippi*. There is room however for doubt on this point, as Charlevoix (*Letters*, p. 293: London, 1763) speaks of the Illinois as cultivating the land after their fashion and as being very laborious; and in Hawkins' Sketch of the Creek Country, p. 34, we are told that "the Shawnees," some of whom, at that time, lived among the Creeks, "were very industrious, worked with the women, and made plenty of corn."

‖ Father Membré, p. 151. Marquette, p. 34, says: "Through what superstition I know not, some Illinois as well as some Nadouessi, while yet young, assume the female dress, and keep it all their life. There is some mystery about it, for they never marry, and glory in debasing themselves to do all that is done by women; yet they go to war, though allowed to use only a club, and not the bow and arrow, the peculiar arm of the men; they are present at all juggleries and solemn dances in honor of the calumet; they are permitted to sing, but not to dance; they attend the councils, and nothing can be decided without their advice; finally, by the profession of an extraordinary life, they pass for manitous (that is, for genii) or persons of consequence." Compare Lafitau, vol. I, pp. 52 and 53, and Lawson's *Carolina*, p. 208. Father Membré, *l. c.*, Hennepin, and La Hontan tell us that these men were reserved for an unnatural purpose, which, according to Charlevoix (Letters, p. 213) and Long (Expedition to the Rocky Mountains, vol. I, p. 129: Philadelphia, 1823), may have been a religious rite or the result of a dream. We are told that the custom existed among the Choctaws, Delawares, and also among the Indians of Florida, though it is denied by Lawson, as far as the tribes of the Carolinas are concerned. It is said to prevail as a religious rite among some of the Pueblo Indians of New Mexico; and Miss Alice C. Fletcher informs me that during her residence among the tribes of the Upper Missouri she saw one instance of a man so clothed, and this was caused by a dream.

tain, however, that slavery was very common among them, that being the usual fate of captives "taken from distant nations in the south and west, where the Illinois go to carry off slaves, whom they make an article of trade, selling them at a high price to other nations for goods."* These tribes lived in villages, some of which were very large, and they also had forts or strongholds for defense in case of necessity.†

Passing over an interval of sixty or seventy years, and coming down to the middle of the eighteenth century, we find the Shawnees and Miamis again established in Ohio and Indiana, in company with the Wyandottes, Delawares, Pottawatamies, and other tribes. Just about this time, too, the white settlers began to push their way across the Alleghany Mountains into the valley of the Ohio, and this brought on that long and bloody struggle between the two races which only ended with the expulsion of the Indians from all that territory, and their establishment on reservations west of the Mississippi. Time and again they "dug up the hatchet," in order to stay the tide of immigration, and though for a while they spread terror all along the frontier, yet, in the end, they were always obliged to yield to the superior force and military skill and discipline of the whites. After every such outbreak they found themselves weaker than before. In retaliation for the outrages which they undoubtedly committed, their country was invaded,‡ their villages burned, their crops destroyed,§ and as the price of each succeeding peace they were obliged to yield more or less of the territory that remained to them. This is a sad chapter in our national his-

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* *Narrative* of Father Marquette, p. 32. *Memoir* of the Sieur de Tonti, *l. c.*, pp. 56–69–71. "The Saukie warriors generally employed every summer in making incursions into the territories of the Illinois and Pawnee nations, from whence they return with a great number of slaves. But those people frequently retaliate:" Carver, *Travels*, p. 47. See also *ibid.*, pp. 344 and 345: London, 1781, and *Relation de la Nouvelle France en l' année*, 1670, pp. 91 and 97: Quebec, 1858.

† *Relation en l' année*, 1670, pp. 98, 99. Carver, *Travels*, p. 36. Father Marest, in note on p. 31 of *Discovery and Exploration of the Mississippi*. *Narrative* of Father Allouez in same, p. 71, with note. Charlevoix, *Letters*, p. 281: London, 1763. *Per contra*, Father Membré, p. 152, asserts that "Tonti taught the Illinois how to defend themselves by palisades," though he himself makes no such claim. The statement is improbable.

‡ "Bowman's *Expedition to Mad River* in 1779, Clark's in 1780 and '82, Logan's in 1786 to the head waters of the Big Miami, and Todd's in 1788 into the Scioto Valley, were chiefly directed against the Shawanees:" Drake, *Life of Tecumseh*, p. 27. Besides these, there were other and more formidable invasions, some of which, like that of St. Clair, A. D. 1791, resulted disastrously to the whites; whilst those of Wayne, 1794, and Harrison, 1811, were among the most successful, inasmuch as in them, not only were the cornfields and villages of the Indians destroyed, but their power was hopelessly shattered by defeat.

§ "In 1780, 200 acres of corn were destroyed at Piqua: *Life of Tecumseh*, p. 29. In 1790, several villages and 20,000 bushels of corn destroyed at the Miami villages on the head waters of the Maumee:" *Our Indian Wards*, by George W. Manypenny: Cincinnati, 1880. In 1791, "400 to 500 acres of corn, chiefly in the milk," destroyed on the Wabash: Butler, *Kentucky*, p. 198: Louisville, 1834.

tory, and yet perhaps more than any other, it justifies the statement that the Indian had made great advance in the scale of civilization. Instead of being the wandering barbarian that he is painted, without fixed home, or any means of subsistence save that furnished by the chase, it presents him to us in the light of a successful farmer—a worthy rival, in this respect, to his white neighbor—fighting desperately a losing battle in defense of all he held most dear. Upon this point Gen. Wayne is certainly competent authority. Writing from Grand Glaize, A. D. 1794, just after the battle of the Maumee, and before the work of destruction had been begun, he uses the following emphatic language: "On the margins of these beautiful rivers, the Miamis of the Lake and the Au Glaize, appear like one continued village for a number of miles, both above and below this place; nor have I ever before beheld such immense fields of corn in any part of America from Canada to Florida.*

This brings us around to the point from which we started, and geographically speaking, completes the circuit. In the course of the investigation, it will be observed that I have taken nothing for granted, but have endeavored to substantiate every assertion by a reference to undoubted sources, retaining as far as possible the very language of the authors. These citations might have been multiplied indefinitely, but it is believed that enough have been given to show:

(1) That the red Indians of the Mississippi Valley lived in fixed villages, which they were in the habit of fortifying by palisades.

(2) That they raised corn in large quantities, and stored it in caches and granaries for winter use.

(3) That whilst, as a fact, the women, children, old men, and slaves always cultivated the fields, yet the warriors cleared the ground, and, when not engaged in war or hunting, aided in working and harvesting the crop, though the amount of such assistance varied, being greater among the tribes south of the Ohio, and less among the Iroquois or Six Nations.

A further examination of these same authorities will show that slavery was more or less common among all the tribes east of the Mississippi; that the rights of property were duly recognized and respected, and that there existed among them a system of inter-tribal traffic, in which, among other things, corn and slaves were bartered for skins and such other articles as were needed.

## II—THE INDIAN AS A WORSHIPPER OF THE SUN.

The question of subsistence being thus disposed of, let us now examine into the form of government and the religious belief of the modern Indians, in order to see whether in these particulars there were any such differences between the state of affairs that can be shown to

*Quoted in *Our Indian Wards*, p. 84: Cincinnati, 1880.

have prevailed among them, and that which is assumed to have existed among the mound-builders, as would warrant the inference that they could not have erected these works. On the part of those who hold that there were such fundamental differences, it is contended that there are certain types of earth-works that were evidently designed for a religious purpose. They are variously termed "temple" mounds and "sacred inclosures,"* are found sometimes singly and sometimes united in a more or less complicated system, and are supposed to indicate that the people who built them were devoted to the worship of the sun.† It is also asserted that the erection of these works involved a species and an amount of labor to which the Indian would not have submitted,‡ and that hence he did not build them.

This is believed to be a fair statement of the argument, which upon examination will be found to be fatally defective in so far as it assumes the very point in dispute. To assert that the Indian would not have submitted to the labor requisite for the construction of these mounds is virtually to beg the whole question. So far is this from being true, that there is probably no fact in American archæology better authenticated than that the red Indian has, within the historic epoch, voluntarily built both mounds and earth-works. This of itself is a sufficient answer to the statement as to what he would or would not have submitted to in the way of work, and, at the same time, it effectually disposes of the theory that only despotic governments could have controlled the amount of labor necessary to the erection of these works, since the form of government existing everywhere throughout the valley of the Mississippi at the date of the arrival of the whites, except, perhaps, among the Natchez Indians,§ was as far removed as possible from anything that savored of despotism. Of course it is not

*Squier, *Ancient Monuments of the Mississippi Valley*, chapters iii and vii: Washington, 1848.

†Foster, *Prehistoric Races of the United States*, p. 182: Chicago, 1873. Short, *North Americans of Antiquity*, p. 100: New York, 1880. Conant, *Footprints of Vanished Races*, pp. 38 and 60: St. Louis, 1879. McLean, *The Mound-Builders*, p. 126: Cincinnati, 1879. Squier, *l. c.*, p. 49. Schoolcraft, *Indian Tribes of the United States*, vol. v. pp. 29 and 61. C. C. Jones, *Antiquities of the Southern Indians*, p. 22: New York, 1873.

‡Foster, *Prehistoric Races of the United States*, p. 349: Chicago, 1873.

§ In the early accounts, the Bashaba of New England, the Werowance of Virginia, the Paraconssi of Florida, not less than the Great Sun of the Natchez, are all represented as absolute rulers, though, to anyone who will take the trouble to read between the lines, it is evident that these were simply other names for the office of chief or sachem, and that the authority of these rulers did not extend any farther than their power to persuade. Even Du Pratz (whose account of the civil polity of the Natchez is most highly colored) virtually admits, vol. II, book IV, section 7, that the war-making power in that nation was vested in a council of old men, and that when war was once declared, the war chief and not the Great Sun led the party, which was composed entirely of volunteers. Under different names we have here the Micco and Tus-tun-nug-ul-gee of the Creeks and the sachem and war chief of the Iroquois, with no more despotism or monarchy in one case than in either of the others.

asserted that these works were as large or complicated as the famous system on the Scioto; nor is it essential to my argument that they should have been intended for the same purpose; but that the two were identical in kind is believed to be beyond dispute, as is also the additional fact that among those known to have been erected by the modern Indians there are those that are on such a scale of magnitude as to prove, beyond doubt, that when the motive was sufficient the Indian did not hesitate to perform, voluntarily and for an indefinite length of time, the same sort of manual labor as that which was necessary for the construction of the more complicated series of works. Upon this point the evidence is very clear; and as there was practically no limit to the time within which these works must have been finished, it follows that their erection by a people living under the same conditions as the Indians must simply have resolved itself into a question of the power and permanence of the motive that impelled them to the undertaking. Clearly, if a regard for the dead, or the necessity for self-protection, could lead the people of a single village to erect, in one case a burial mound and in the other a breastwork or fort, there can be no reason why a motive that affected a whole tribe and continued to influence successive generations might not have led to works as much greater than these as the one motive is more general and permanent than the other. Cologne cathedral is, to some extent, a case in point. That building was begun some five hundred years ago, at a time when the religious feeling of the people of that country was wont to manifest itself in such outward marks of devotion, and though the work has dragged as the ages rolled on and opinions changed, yet the very same motive or motives that led to its commencement, acting upon succeeding generations, have resulted at last in the completion of that superb structure. This being admitted, and I do not see how it can well be denied, there only remains for me to prove the existence of some adequate motive among the Indians in order to justify the conclusion that they could have built these works, even those of the largest size and most complicated pattern.

Under ordinary circumstances this is a task that I should hardly venture to undertake. To attempt to point out the motive that led the people of a village or a tribe to execute a certain piece of work, requiring the united labor of a large number of persons for an indefinite time, especially when the purpose or end for which that work was intended is itself a matter of grave doubt, seems like a hopeless undertaking; and yet, with all due deference be it spoken, this is precisely what the advocates of the mound-builder theory have done, and in so doing they have marked out the course that this investigation must follow.

Reasoning from analogy—an uncertain guide, at best, in matters scientific—they not only tell us that a certain class of these works were designed for a religious purpose, but they assert that they were built

by a people who worshiped the sun; and they even go so far as to use this as an argument why they could not have been erected by the red Indian. That some of these works were, in some way, connected with this cult is extremely probable; at all events, in view of the plausible explanation it gives of their origin, the statement is admitted to be true; but to assume that this furnishes a sound basis for the next step in the argument, and authorizes the inference that the red Indian could not have built them, is without warrant, either in fact or logic. Indeed, so far is it from being an argument in favor of this theory, that it is believed to tell, with disastrous effect, against it, since it can be shown, on undoubted authority, that everywhere in the valley east of the Mississippi the Indian was a sun-worshipper,* and thus, of course, he and the mound-builder must have had the same religious cult, even according to the admissions of those who hold that the two belonged to different races and represented different phases of civilization. This being the case, and it being further admitted that it was this cult that led the mound-builders to erect works like the so-called sacred inclosures of southern Ohio, it must follow that there can be no reason why the same cult should not have produced, among the Indians, precisely similar results.

To the argument when stated in this fashion, the only answer logically possible is a denial that the Indians were sun-worshipers, all others being barred by the terms of the statement; and as this is the course that the discussion must inevitably take, it behooves me to strengthen this point as much as possible. To this end an appeal to the early records again becomes necessary, and though it seems like a waste of time thus to "thrash old straw," yet the fact that recent writers on this subject have either entirely ignored the existence of sun worship among the modern Indians, or else have limited it to a few tribes,† is proof positive of the necessity for repeating the evidence which has led me to a contrary conclusion. In doing this, however, the order followed in investigating the question of subsistence will be reversed. Instead of beginning with the Huron and Algonquin families, as was done in that

* "The tribes of the New World chose the sun as the object of their adoration:" Brinton, *Notes on the Floridian Peninsula*, p. 126, Philadelphia, 1859. "With almost all the aborigines there is proof - - - of the former worship of the sun:" Bradford, *American Antiquities*, p. 181, New York, 1841. "The United States Indians regarded the sun as the symbol of light, life, power, and intelligence, and deemed it the impersonation of the Great Spirit. They sang hymns to the sun and made genuflections to it:" Schoolcraft, *Indian Tribes*, vol. v, p. 407, and vol. III, pp. 60 and 64. "The religions or superstitions of the American Nations - - - are only modifications of that primitive system which has been denominated sun or fire worship:" Squier, *Serpent Symbol in America*, p. 111, New York, 1851. See also Tylor, *Primitive Culture*, vol. II, pp. 287 *et seq.*, Boston reprint 1874. Nuttall, Travels in Arkansas, p. 277, Philadelphia, 1821.

† *Footprints of Vanished Races*, p. 61: St. Louis, 1879.

case, the tribes south of the Ohio, called by Schoolcraft the Appalachians (though they do not all belong to the same stock or family), will be first considered. This change is deemed advisable for the reason that the religious rites and observances of these tribes are better known than are those of any other nation in the Mississippi Valley, and because, further, it is only by the light of this knowlegde that it is possible to interpret customs once prevalent elsewhere, but which have either wholly died out or lost much of their significance. As an instance of this, take the institution for keeping up a perpetual fire,* which seems, at one time, to have been very general among the tribes north of the Ohio, but which disappeared soon after the arrival of the whites, though we are told that its rites and duties were still fresh in the recollection of the Indians. Of itself, the fact that this institution had once prevailed extensively among tribes both of the Huron and Algonquin families might not be considered as settling definitely their form of religion; but if it be taken in connection with the very prominent part this rite held in the religious observances of the sun-worshiping tribes of the Gulf States, it will be seen that it forms an important link in the chain of evidence that points to the existence of one and the same form of worship among these different nations. Other instances of a similar character will doubtless occur in the course of this investigation; and my object in calling attention, at this time, to the sudden disappearance, over such a wide area, of what must have been an important religious rite, is not so much to mark the identity that once existed in the ritual of these widely separated nations, as it is to indicate the method that it is proposed to adopt in the treatment of this and similar cases. This mode of reasoning is believed to be perfectly fair and legitimate, though of course its efficacy will depend upon the establishment of the truth of the proposition that the southern Indians were sun-worshipers. Fortunately this is a matter about which there can not be much doubt.

* General Lewis Cass in Notes to *Sanillac*, a poem by Henry Whitney: Boston, 1831. Brinton, *Myths of the New World*, p. 150: New York, 1876. Schoolcraft, *Address before N. Y. Historical Society*, 1846, quoted in *Serpent Symbol in America*, p. 129. "The general council of the Five Nations was held at Onondaga, where there has, from the beginning, been kept a fire continually burning, made of two great logs, whose flames were never extinguished:" Colden, *Five Nations*, vol. I, p. 167: London, 1747. This language may be metaphorical, and the "fire" spoken of may mean a "council fire," and I am perfectly willing to admit that it does, though Lafitau, vol. I, pp. 340 and 341, speaking of the Iriquois, tells us that "Les Sauvages ont encore plus perdu de leurs coutûmes depuis ce temps-là; ils le reconnoissent eux-mêmes, et y ont regret; car dans les malheurs qui leur arrivent, ils disent qu'ils ne doivent pas s'en plaindre, et que c'est une punition pour avoir abandonné l'usage de leurs retraites, et de leurs jeûnes."

La Vega,* Laudonière,† and others,‡ some of whom wrote in the latter part of the sixteenth century, bear witness to the fact in the most unmistakable language, and their statements are confirmed by all the later writers.§ To enumerate these latter would be simply to call the roll of all who have written upon the subject, and however interesting this might be to the special student in a bibliographical point of view, it would soon become monotonous and "caviare to the general." For this reason, I shall confine myself to a rapid survey of some of the religious customs that prevailed among these tribes, and will only make such use of authorities as may be necessary to establish the truth of the propositions advanced.

Speaking in a general way, then, it may be said of these nations that among some of them "the sun was regarded as one of the great deities; by others it was looked upon as the symbol or representative of the chief deity, and yet again by others it was considered as the supreme deity himself."‖ As part and parcel of this worship, there were certain rites and ceremonies, among which that of keeping up a perpetual fire was one of the most striking. This fire was kept burning in honor of the sun,¶ and was regarded as being too sacred to be

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* "Les peuples de la Floride tiennent le Soleil et la Lune pour des Divinites:" *Histoire de la conquête de la Floride*, p. 11; Paris, 1709. According to the Gentleman of Elvas, De Soto, in order to ingratiate himself with the tribes through whose dominions he was passing, represented himself as being a child of the Sun. "Dry up the river," answered the Cacique of Quigalta, "and he would believe him:" Narrative of the Expedition of Hernando de Soto in *Hist. Coll. of Louisiana*, part II, p. 187.

† "They sing praises to the Sun, ascribing unto him the honor of the victory. They have no knowledge of God, nor of any religion, saving that which they see, as the Sun and the Moon:" History of the first attempt of the French to colonize Florida, A. D. 1562, in *Hist. Coll. of Louisiana*, new series, pp. 171–252, and 253: New York, 1869.

‡ Le Moyne, plate XXXV and explanation, Franckforto ad Moenum, 1591. See also plate in preface to vol. VI of Herrera's *History of America*, in which the Indians of Florida are represented as "sacrificing their first-born to the Sun:" London, 1740. "Les Apalachites adoraient le soleil de même que la plupart des plus celebres peuples de l'Amerique:" Rochefort *Histoire des Antilles*, p. 412: Rotterdam, 1665. Confirmed by Herrera, pp. 328–355 of vol. V, and p. 24 of vol. VI: London. 1740. "Le Soleil est en quelque façon l'unique Divinité des Floridiens, tous leurs Temples lui ont consacrées:" Charlevoix, *Nouvelle France*, vol. I, p. 41.

§ Consult Jones, *Antiquities of the Southern Indians*, chapters i and xix: New York, 1873. Brinton, *Floridian Peninsula*, chapter iii, section 3: Philadelphia, 1859. Tylor, *Primitive Culture*, vol. II, p. 287 *et seq.*: Boston reprint, 1874. Squier, *Serpent Symbol in America*, chap. iv: New York. 1851. *Ancient Monuments of the Mississippi Valley*, p. 123: Washington, 1848.

‖ This is the classification made by Tylor, *Primitive Culture*, vol. II, p. 287, of the beliefs of "the ruder tribes" of the northern continent. It seems to me that it is equally applicable to the tribes living on the lower Mississippi and along the Gulf coast, and I have adopted it, even though those nations are sometimes considered, on what are believed to be insufficient grounds, as occupying a somewhat higher place in the scale of civilization than their neighbors north of the Ohio.

¶ Charlevoix, *Letters*, p. 313: London, 1763.

used for ordinary purposes. It was fed with sticks or billets of wood without the bark, placed so as to radiate from a common center somewhat like the spokes of a wheel, the fire occupying the center or hub. It was kept in buildings or temples erected for the purpose, in which were also preserved the bones of the dead chieftains, neatly done up in cane baskets. Priests or guardians were appointed to watch over this fire, and see that it never died out, as its extinguishment was thought to forebode dire evil to the tribe.* In case such a thing did happen, either by accident or through carelessness, the fire could only be rekindled by brands taken from that kept burning in the temple of the Maubiliens.†

First among the priests or guardians of the temple and fire among the Natchez was the chief of the tribe, or, as he was called, the Great Sun.‡ Every morning at sunrise he appeared at the door of his cabin, and turning toward the east "he howled three times," bowing down to the earth. Then a calumet, used only for this purpose, was brought him, and he smoked, blowing the smoke of the tobacco first towards the sun and then towards the other three quarters of the world.§ He acknowledged no superior but the sun, from which he pretended to derive his origin.‖

These temples did not differ materially from each other, nor from the other cabins, especially those of the Indian chiefs. The description which the Sieur de Tonti has left us of the one among the Tensas, visited by him

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* Charlevoix *Letter* no. XXIX, pp. 308 *et seq.*: London, 1763. Du Pratz, *History of Louisiana*, vol. II, chapter 3, sections 2 and 4: London, 1763. Memoir of Tonti in *Hist. Coll. of Louisiana*, part I, p. 61. Father Le Petit in *Hist. Coll. of Louisiana*, part III, note to p. 140 *et seq.* La Vega, *Conquête de la Floride*, vol. I, p. 266 *et seq.*: Paris, 1709. Gentleman of Elvas in *Hist. Coll. of Louisiana*, part II, p. 123. Letter of Father Gravier in same, second series, pp. 79 *et seq.*: 1875.

† Charlevoix, *Letters*, p. 323; London, 1763.

‡ Du Pratz, *History of Louisiana*, vol. II, p. 212: London, 1763.

§ Charlevoix, *Letters*, p. 315. Father Le Petit in *Hist. Coll. Louisiana*, part III, note to p. 142. Father Donay's Narrative of La Salle's attempt to ascend the Mississippi in 1687; published in Shea's *Discovery and Exploration* of that river, p. 228. It was in this expedition that La Salle was murdered, and the good father's account relates to the tribes that were then living in what are now the States of Texas, Louisiana, and Arkansas. He says: "The Sun is their divinity, and they offer it in sacrifice, the best of their chase in the chief's cabin. They pray for half an hour, especially at sunrise; they send him the first whiff of their pipes, and then send one to each of the four cardinal points." As late as the beginning of the present century, Nuttall tells us that, according to the testimony of a Quapaw chief, the "Osages smoked to God or the sun, and accompanied it by a short apostrophe:" *Travels into the Arkansas Territory* p. 95; Philadelphia, 1821.

‖ Charlevoix, *Letters*, p. 315. This belief was not confined to the Natchez, as the Hurons and also the tribes of the Floridian Peninsula asserted the same thing of their chiefs. See Charlevoix, *Letters*, p. 314, for the former, and Lafitau, *Moeurs des Sauvages Ameriquains*, vol. I, pp. 181 and 456 for the latter. Bartram, *Travels through Florida*, p. 496, says that among the Creeks, "the Micco seems the representative of the Great Spirit."

during the course of his trip down the Mississippi with La Salle, A. D. 1682, will, with but few changes, apply equally well to all of them. After premising that these tribes "have a form of worship, and adore the sun,"* he goes on to say that the temple is very like the cabin of the chief, which stands opposite, except that on top of it there were the figures of three eagles which looked toward the rising sun. It was about 40 feet square, and the walls, 10 feet high and 1 foot thick, were made of earth and straw mixed. The roof was dome-shaped, and about 15 feet high. Around this temple were strong mud walls, in which are fixed spikes, and on these are placed the heads of their enemies, whom they sacrificed to the sun. Within it there is an altar, and at the foot of this altar three logs of wood are placed on end, and a fire is kept up day and night by two old priests, who are the directors of their worship.†

We are are also told that, at one time, these temples were quite common throughout all the vast region then known as Florida, a majority of the tribes and even many of the villages having their own, and keeping up in them perpetual fires.‡ Geographically speaking, they are found all the way from Arkansas to the southern extremity of the peninsula of Florida; and in point of time they cover the one hundred and eighty years embraced between the expedition of De Soto and the visit of Charlevoix in A. D. 1721.§ About this time they seem to have gone somewhat out of fashion, as we are told that the one among the Natchez was the only one left; and although that is said to have been held in great veneration "by all the savages which inhabited this vast continent," and the eternal fire was still kept up, yet it is evident from the neglected and unguarded condition in which Charlevoix found it‖ that it had lost much of its sacred and distinctive character. Indeed, he tacitly admits as much, and probably assigns the true cause when he

* Memoir of Tonti in *Hist. Coll. of Louisiana*, part I, pp. 61 and 64.

† Memoir of Tonti in *Hist. Coll. of Louisiana*, part I, pp. 61 *et seq.* *Narrative of La Salle's voyage down the Mississippi* by Father Membré, p. 171. Speaking of the Indians of the lower Mississippi, the worthy father says: "We remarked a particular veneration they had for the sun, which they recognized as him who made and preserves all." Compare this description of the temple of the Tensas with that of similar buildings among other tribes as given in Charlevoix, *Letters*, pp. 312 *et seq.*, and in *La Nouvelle France*, vol. III, p. 381: Du Pratz, *History of Louisiana*, vol. II, chap. 3, sections 2 and 4; La Vega, premiere partie, pp. 266 *et seq.;* Gentleman of Elvas in *Hist. Coll. of Louisiana*, part I, p. 123, and Father Le Petit, in the same, part III, note to pp. 141 *et seq.* This latter author says of the Natchez: "The sun is the principal object of veneration to these people; as they cannot conceive of anything which can be above this heavenly body, nothing else appears to them more worthy of their homage."

‡ Charlevoix, *Letters*, p. 323. Du Pratz, vol. II, pp. 210 and 11. Father Le Petit, *l. c.*, note on p. 144.

§ La Vega, *Conquête de la Floride*, premiere partie, pp. 264 *et seq.* *Ibid.*, seconde partie, p. 89: Paris, 1709. Gentleman of Elvas, *l. c.*, p. 123. Charlevoix *Letter*, no. XXIX: London, 1763. Du Pratz, vol. II, p. 211: London, 1763

‖ Charlevoix, *Letters*, pp. 313 and 323.

ascribes it to the fear lest the French should violate these last resting-places of the dead,* as they had done with the temple of Oumas† a few years before.

Some twenty-five years later, in the time of Adair, who lived and traded among the Chickasaws, Creeks, and Choctaws for many years subsequent to 1735, the change was even more perceptible. It is true that the tribes constituting the Creek or Muscogee confederacy kept up many of the peculiar usages of the Natchez, and continued to venerate the sun, as they certainly did down to a comparatively recent period;‡ and in describing their religious ceremonies, Adair still speaks of a "sacred fire," "holy places," "synhedria," etc.;§ but it is evident that in so doing he has been betrayed by his wild notions as to the identity of the American Indians with the lost tribes of Israel, into the adoption of a terminology that is not warranted by the facts. Temples such as the one described among the Tensas, and which, as we have seen, were once common among all the Floridian tribes, no longer existed, and in their stead we find the state house, rotunda, hot house, or simple council chamber, such as it was known to the Creeks and Cherokees. In connection with the disappearance of the temples proper among these nations, there seems to have been a corresponding decrease in the number and purity of their religious rites and ceremonies. Du Pratz|| mentions the fact, ascribing it to the decrease in population, whilst Adair,¶ mourning over what he is pleased to consider the religious degeneracy of the times, complains that "their primitive rites are so corrupted within the space of the last thirty years that, at the same rate of declension, there will not be long a possibility of tracing their origin but by their dialects and war customs." Especially is this said to be true of the Cherokees, whom he stigmatizes as a nest of apostate hornets.**

A few years later, say during the last quarter of the eighteenth century, and the change is complete. A temple is no longer even spoken of, though the council house, which seems to have taken its place as the scene of their religious rites and festivities, inherited something of its sacred character. It was still placed upon an artificial mound,†† as it had been among the Quapaws of Arkansas,‡‡ the Natchez of Louisiana,§§

*Charlevoix, *Letters*, p. 313: London, 1763.

†Lafitau, *Moeurs des Sauvages Ameriquains*, vol. I, p. 168: Paris, 1724.

‡Nuttall, *Travels into the Arkansa Territory*, p. 277: Philadelphia, 1821.

§ Adair, *History of the North American Indians*, pp. 30 and 98, *et seq.*: London, 1775.

|| *History of Louisiana*, vol. II, p. 210: London, 1763.

¶ *History of North American Indians*, pp. 81 and 98.

** *North American Indians*, p. 81.

†† Bartram, *Travels through Florida*, p. 367, *et seq.*: Philadelphia, 1791. See also MSS. of the same author quoted by Squier in *Smithsonian Contributions to Knowledge*, vol. II, pp. 136, *et seq.*, and Adair, *North American Indians*, p. 421.

‡‡ La Vega, *Conquête de la Floride*, seconde partie, p. 89: Paris, 1709.

§§ Du Pratz, vol. II, p. 211: London, 1763. Father Le Petit, in *Hist. Coll. of Louisiana*, part III, note to p. 140.

and other southern tribes; and here the old men of the village were accustomed to meet every evening to talk over public affairs; and here also took place many of their feasts and dances when the weather precluded the use of the open square in front.* Women were no longer shut out from its sacred precincts, but were permitted under certain conditions to take a subordinate part in the ceremonies, except, perhaps, among the Creeks, among whom, according to Bartram, it was still deemed an offense worthy of death for a woman to enter this rotunda.† He also tells us that it was within this building that the new fire was kindled on the occasion of the feast of first fruits, and it was here that, under guard of the priests, "they seem to keep up the eternal fire."‡ This however had lost its original form, and was now spiral in shape.§ Its sacred character too was gone, for the houseless pauper could now bask in its warmth undisturbed by priest or prophet; and when the evening dance or the council was over, he might find a night's lodging within the precincts of the temple itself.||

Another very interesting rite was that of annually putting out all the fires of the tribe, and kindling them anew from sacred fire produced by friction. This ceremony took place at the Feast of the Busk or offering of first fruits, which seems to have been very general throughout this region.¶ Indeed, Schoolcraft tells us that it also prevailed among the Huron and Algonquin families north of the Ohio, and that it extended

* Hawkins, *Sketch of the Creek Country*, p. 72. Adair, p. 18. Bartram, *Travels through Florida*, pp. 369 and 516. Schoolcraft, vol. v, p. 265. Timberlake, *Memoirs relating to the Cherokees*, p. 32.

† Bartram, MSS. quoted in *Smithsonian Contributions to Knowledge*, vol. II. p. 138: Washington, 1851.

‡ *Ibid.*, p. 138. "Muscogulges pay a kind of homage to the Sun, Moon, and Planets:" Bartram, MSS. quoted in Serpent Symbol, p. 69: New York, 1851. "Cherokees adore Sun and Moon:" Payne, MSS. quoted in same, p. 68. Indians of Southern States appear to have been "originally worshipers of the Sun. The Chahta, when he has greatly misbehaved, utters these ejaculations: when the Sun forsakes a man he will do things he never thought to do. The Sun is turned against me, therefore have I come to this:" Pitchlynn, quoted by Buckingham Smith in Notes to his Translation of the Relation of Cabeça de Vaca, p. 171: New York, 1871.

§ Bartram MSS., *l. c.*, p. 138. Hawkins, p. 71. The latter author says: "In the center of the room, on a small rise, the fire is made of dry cane or old pine slabs, split fine, and laid in a spiral circle." See also Lawson, *Carolina*, p. 38: London, 1718. In this connection it is interesting to note that the Abenaquis, of New England, were in the habit of practicing divination by the manner in which the fire would "run" in a carefully prepared powder made from cedar. Lafitau, vol. I, p. 387, gives an account of it, also the argument by which an Indian woman justified the practice.

|| Hawkins, *Sketch of the Creek Country*, p. 72. Schoolcraft, *Indian Tribes of the United States*, vol. v, p. 265.

¶ Joutel, Journal in *Hist. Coll. of Louisiana*, part I, p. 151. Father Le Petit in same, part III, note on p. 144. Nuttall, *Travels in the Arkansa Territory*, p. 96. Brinton, *Myths of the New World*, p. 150: New York, 1876. Du Pratz, *Louisiana*, vol. II, p. 189. Timeerlake, *Memoirs relating to the Cherokees*, p. 65: London, 1765.

to the tribes west of the Mississippi.* He also adds, that in every case it was attended with many ceremonies, though it does not seem to have been celebrated anywhere north of the Ohio with the same solemnity that it was among the nations that formerly inhabited the Gulf States,† or, at all events, our accounts of such celebrations are not so full and explicit. Adair, who lived among these people for many years, and who, aside from his notions about the identity of the Indians with the Israelites, is usually trustworthy, describes this festival at great length, as does Bartram, Hawkins, and others.‡ From their accounts I have made up the following summary, which may not be uninteresting: When the time for holding this festival was fixed, the people of the village put their town in order, prepared new clothes for themselves, and then, having partaken of the "black drink,"§ they entered upon a rigorous fast of two days, during which they abstained from the gratification of every sensual appetite. On the morning of the third day a supply of old food was brought to the square, all vestiges of which were removed before noon. As the sun began to decline, the fires were extinguished in every hut, and universal silence reigned. The chief priest then took a piece of dry poplar, willow, or white oak, and having cut a hole "so as not to reach through it, he sharpened another piece, and placing that within the hole, he drilled it briskly for several minutes, till it began to smoke; or by rubbing two pieces together for about a quarter of an hour, by friction, he collected the hidden fire." It was then brought out of the temple in an earthen dish and placed upon an altar that had been previously prepared in the square. Its appearance brought joy to the hearts of the people, as it was supposed to atone for all past crimes, except murder. A general amnesty was proclaimed, except for this one crime, and all malefactors might now return to their villages in safety. A basket of new fruits was then brought, and the fire-maker took some of each kind, and covering them with bear's grease, he offered them up as a sacrifice to the holy spirit of fire. He likewise consecrated the plants from which the "black drink" was prepared, by pouring some of the decoction into the holy fire. The women ranged themselves around the square, when each received a portion of the new and pure flame, with which they kindled anew the household fires. Then they prepared, in the best manner, the new corn and fruits, and brought them to the square, where the people were assembled, apparelled in their new clothes and decorations. "The men having regaled themselves, the remainder

* *Notes on the Iroquois*, p. 85, *et seq.*: New York, 1846. *Indian Tribes of the United States*, vol. III, p. 227. Catlin, *North American Indians*, vol. I, p. 189: London, 1848.

† Schoolcraft, *Indian Tribes of the United States*, vol. V, p. 104.

‡ Adair, *History of North American Indians*, argument VIII. Bartram, *Travels through Florida*, pp. 509 and 510. Hawkins, *Sketch of the Creek Country*, pp. 75, 78. See also note 187.

§ Made from the Ilex Cassine L., called Cassena or Youpon.

was carried off and distributed among the families of the village. The women and children solaced themselves in their separate families, and in the evening repaired to the public square, where they danced, sung, and rejoiced during the whole night, observing a proper and exemplary decorum; this they continued three days, and on the four following days they received visits and rejoiced with their friends from neighboring towns, who had all purified and prepared themselves."

There were other rites and ceremonies connected with the worship of these tribes that might be studied to advantage; but those reported above were the most important, and will give a very good idea of the ritual as developed among these people. As has been said, the religious cult seems to have reached a higher level here than it attained elsewhere in the Mississippi Valley;* and hence, in comparing, as we shall now do, their rights and customs with those of the tribes that lived north of the Ohio, and belonged to the Huron and Algonquin families, we must expect to find among the latter a falling off in the forms and ceremonies, rude as they undoubtedly were, that characterized the religious observances of the tribes with which we have been dealing.

Beginning with the tribes along the south Atlantic coast we find that temples existed as far north as Virginia, and that the same religious customs obtained as did among the sun-worshiping nations of the lower Mississippi,† Lawson, Capt. Smith, and Beverly speak of these temples, or quioccosan, as they are called, as being very sacred, none but the king conjurer and a few old men being permitted to enter them.‡

* Tylor, *Primitive Culture*, p. 288. Boston reprint, 1874.

† After describing the temple and religious customs of the Natchez, Lafitau, vol. I, p. 168, Paris, 1724, says: "Quelques peuples de la Virginie et de la Floride ont aussi des Temples et a peu près les mêmes devoirs de Religion." "Sunne, Moone, and Starre as pettie Gods." Harriot in Hakluyt's *Voyages*, vol. III, p. 336: London, 1810. "Adore fire, water, lightning." Capt. Smith, *Virginia*, p. 34: London, 1632. "Their religion consists of adoration of the sun and moon:" *Carolina*, by Thomas Ash, p. 36: London, 1682. "In the morning, by break of day, before they eat or drink, both men and women and children that be above 10 years of age, run into the water, there wash themselves a good while, till the sun riseth, then offer sacrifice to it, strewing tobacco on the water or land, honoring the Sun as their God; likewise they do at the setting of the sun:" Observations in Virginia by George Percy, in Purchas *Pilgrims*, vol. IV, p. 1690. "It is a generall rule of these people when they swere by their God, which is the Sunne, no Christian will keepe their Oath better upon this promise. These people have a great reverence to the Sunne above all other things at the rising and setting of the same, they sit downe, lifting up their hands and eyes to the Sunne, making a round circle on the ground with dried Tobacco; then they begin to pray, making many Devilish gestures with a Hellish noise, foming at the mouth," etc.: *Ibid.*, p. 1690: London, 1625. "They give great reverence to the Sun:" Strachey, Historie of Travaile into Virginia, in publication of the Hakluyt Society, p. 93: London, 1849.

‡ Beverly, *History of Virginia*, part III, p. 28: London, 1705. Lawson, *Carolina*, p. 211: London, 1718. Capt. Smith, in Purchas *Pilgrims*, vol. IV, p. 1701: London, 1625.

The last-named writer gained access to one during the temporary absence of the guardians, and from the account he has left of it, there can not have been much difference between it and similar buildings among the tribes living further to the southward. He tells us that it was used as a receptacle for the bones of the deceased chieftains, which were done up in much the same manner as they were in the temple of the Natchez. It also contained a human figure or idol, which was variously termed Okee, Quioccos, or Kiwasa; and I mention this fact particularly, as it is one of the very few instances indicating the existence of idolatry among the Indians of the United States that is entitled to any weight, though there are reasons why even this statement should be taken with many grains of allowance. Round about the house, at some distance from it, were set up posts with faces carved on them and painted.* According to Strachey, the priests who had the care of these temples "mainteyne a continuall fier in the same upon a hearth somewhat neere the east end." Hariot † speaks of "sacred fires," in which tobacco was offered as a sacrifice; and in the plate which De Bry ‡ gives of this temple a fire is represented as burning on the floor. We are also told that these tribes "annually present their first fruits of every season and kind, namely of birds, beasts, fish, fruits, plants, roots, and of all other things which they esteem either of profit or pleasure to themselves; and that they repeat these offerings as frequently as they have great successes in their wars, or their fishing, fowling, or hunting. It was also their custom to offer sacrifice upon almost every occasion. When they travel or begin a long journey, they burn tobacco instead of incense to bribe the sun to send them fair weather and a prosperous voyage. Likewise, when they return from war, from hunting, from fresh journeys, or the like, they offer some proportion of the spoils of their chiefest tobacco, furs, and paint, as also the fat and choice bits of their game," § in which latter respect they did not differ from the Creeks and Chickasaws. ||

As we go towards the north the temples disappear, although traces of the rites that were associated with them remain. We are still among tribes belonging to the Algonquin family, and their religious belief is said to have resembled that of "cognate tribes of other stocks

* Compare La Vega, *Histoire de la Floride*, première partie, p. 267 *et seq.*: Paris, 1709. Charlevoix *Letter* no. xxix: London, 1763. Du Pratz, *Louisiana*, vol. II, p. 211: London, 1763. Father Le Petit, in *Hist. Coll. of Louisiana*, part III, note to p. 141.

† Virginia, *l. c.*, p. 90. Hariot in Hakluyt's *Voyages*, vol. III, p. 330: London, 1810.

‡ *Admiranda Narratio*, plate xxii, Franckforti ad Moenum, 1590. Beverly, *Virginia*, plates xi and xii: London, 1705.

§ Beverly, *Virginia*, book III, pp. 12 and 13. Capt. Smith, in Purchas *Pilgrims*, vol. IV, p. 1702.

|| Adair, *History of the North American Indians*, pp. 117–118. He adds: "Formerly every hunter observed the same religious economy, but now it is practiced only by those who are most retentive of their old religious mysteries."

and lineage,"* whatever that may mean. Amid a host of supernatural beings or Manitous, big and little, good and bad, they seem to have recognized Michabou or Atahocan, the great hare, as the chief.† According to Schoolcraft, they "located him in the sun or moon, or indefinite skies. In their pictorial scrolls they painted the sun as a man's head surrounded with rays, and appeared to confound the symbol with the substance. They attributed light and life, vitality and intelligence, the world over, alike to Monedo and to Gézis, the sun."‡

Of the religious rites of these tribes, our accounts, though not so full and explicit as might be desired, are still sufficiently so to indicate most clearly the existence of the same form of worship as that which prevailed among the tribes of Virginia and Florida. The Chippewas,§ as we have seen, kept up the eternal fire until comparatively recent times. They said they had received the institution from the Shawnees, and this is probable, as that tribe, although belonging linguistically to the Algonquin family, was more or less closely connected with the Creeks, Natchez, and other sun-worshiping tribes of the South,‖ and must perforce have been familiar with, if not a sharer in, their religious

*Schoolcraft, *Indian Tribes*, vol. v, p. 402. Hariot, A. D. 1586, speaking of the Virginia Indians, says: "They believe in many gods and in one chief God, who is eternal and the creator of the world. After this he created an order of inferior gods to carry out his government, among whom were the sun, moon, and stars. The waters were then made, out of which by the gods came all living creatures. He next created a woman, who, by the 'working' of one of the gods, brought forth children, and 'in such sort they had their beginning.' They thought the gods were all of human shape, and so represented them in their temples where they 'worship, sing, pray, and make many times offering unto them. They believed in the immortality of the soul, which was destined to future happiness in heaven, or to inhabit Popogusso, a pit or place of torment:'" Hakluyt, *Voyages*, vol. III, p. 336: London, 1810. This account is so evidently colored by Christian ideas that it is almost worthless for purposes of comparison, and the same may be said of Du Pratz's statement of the religious belief of the Natchez, in which the interpolations are even more marked. For obvious reasons, the study of the religious beliefs of the aborigines is attended with many difficulties, though I am inclined to think that Parkman is not far wrong when he asserts that "the primitive Indian yielding his untutored homage to One All-pervading and Omnipotent Spirit is a dream of poets, rhetoricians, and sentimentalists:" *Jesuits in North America*, p. lxxxix of the preface: Boston, 1867.

†Charlevoix, *Letters*, p. 218. La Potherie, *Historie de l'Amerique*, vol. II, p. 3: Paris, 1753.

‡Schoolcraft, *Indian Tribes*, vol. v, p. 402.

§See *ante*, foot-note on p. 537. "Vestiges of the former prevalence of fire worship exist over immense spaces, and its rites are found to lie at the foundation of the aboriginal religion throughout the geographical area of the United States. In one of the Indian traditions the preservation of a sacred fire is carried to the banks of Lake Superior:" Schoolcraft, *Indian Tribes*, vol. v, p. 64.

‖*Archæologia Americana*, vol. I, p. 273. Adair, *Hist. North American Indians*, p. 410. Hawkins, *Sketch of the Creek Country*, pp. 16–18. Lawson, *Carolina*, p. 171. Charlevoix, *Nouvelle France*, vol. I, p. 40: Paris, 1744. *Historical Collections of Louisiana and Florida*, new series, p. 126: New York, 1869. Milfort, *Memoirs sur le Creek*, p. 283: Paris, 1802. Schoolcraft, *Indian Tribes*, vol. v, p. 260.

observances. Indeed, the "ceremony of thanksgiving for the first fruits of the earth," as observed among the Shawnees, attended as it was by a general amnesty for all crimes except murder, and also the custom of "suspending the head, horns, and entrails of the animals killed for the sacrifice on a large white pole, with a forked top, which extends over the house,"* are so similar to the same rites as practiced, respectively, among the Creeks† and the Indians of the Floridian Peninsula‡ as to leave no doubt upon this point, even if we had not positive assurance from other quarters that they looked upon the sun as the Great Spirit, for the reason that he "animates everything, and is, therefore, clearly the master of life."§ The Delawares were closely connected with the Shawnees, and appear to have had many of the same religious ceremonies. They offered sacrifices of tobacco to the sun,‖ and had a festival in honor of fire, which (Lieut. Whipple, in vol. III, p. 20, of the *Explorations of a Railroad to the Pacific*) "they renew once a year." They also, according to Van der Donck, swore by the sun, saying: "that he sees all. They regard him and the moon as being better than all the Christian gods, for they warm the earth and cause the fruits to grow."¶

Among the New England Indians the same form of worship prevailed. Roger Williams and others tell us that they worshiped the sun for a god,** and had a festival at harvest time.†† This is confirmed by Cotton Mather so far as relates to the worship of the sun and moon, and he adds that they believe that every remarkable creature has a peculiar god within it or about it.‡‡ In the famous Dighton rock inscription which stands in the country once held by the Wampanoags the symbol of the sun was discovered by Chingwauk, the Algonquin Meda,§§ and in this same region lived the Narragansetts, who, according to

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* *Archæologia Americana*, vol. I, p. 286.

† See above, note ‡, on page 543; and Lafitan, vol. I, p. 180.

‡ Le Moyne, in De Bry, pl. xxxv. Franckforti ad Moenum, 1591.

§ Gregg, *Commerce of the Prairies*, vol. II, p. 237: New York, 1845.

‖ Loskiel, *History of the Mission of the United Brethren among the Indians of North America*, pp. 41 and 43: London, 1794.

¶ In *Collections New York Hist. Soc.*, new series, vol. I, pp. 213–14. Compare *Doc. Hist. of New York*, vol. III, p. 22.

** Williams's *Key*, pp. 39-77-110. "Some for their God adore the sun:" Gookin, in *Coll. Mass. Hist. Soc.*, first series, vol. I, p. 154. "Devotion to the principles of sun-worship - - - spread to the prominent peaks of the Monadnock and to the waters of the Narragansett:" Schoolcraft, *Indian Tribes*, vol. V, p. 104. "Ils croyent un Dieu, ce disent ils: mais il ne scauent le nommer que du nom du soleil, - - - quand ils etoient en necessité, il prenoit sa robe sacrée, et se tournant vers l'Orient disait: Nostre soleil, ou nostre Dieu donne-nous a manger:" *Relation des Jesuites*, A. D 1611-1522, vol. I, p. 20: Quebec, 1858. Indians of Martha's Vineyard "begged of the sun and moon - - - to send them the desired favor:" *Mass. Hist. Coll.*, first series, vol. I, p. 140.

†† Williams's *Key*, p. 111.

‡‡ Magnalia, vol. I, p. 505; Hartford, 1820.

§§ Schoolcraft, *Indian Tribes*, vol. V, p. 64.

Winslow, "had a great spacious house, wherein only some few (that are, as we may term them, priests) come; thither at certain known times resort all their people, and offer all the riches they have to their gods, as kettles, skins, hatchets, beads, knives, etc., all of which are cast by the priests into a great fire that they make in the midst of the house and there consumed to ashes. To this offering every man brought freely, and the more he is known to bring, hath the better esteem of all men. This the other Indians about us approve of as good, and with their sachems would appoint the like."* Farther to the east the Souriquois, as we are told by Father Sagard,† had the same form of worship.

In the Northwest, the sun and thunder were the gods of the tribes that lived around Green Bay, and in all that region out of which were subsequently formed the States of Wisconsin and Illinois.‡ When the Illinois came to meet Marquette on the occasion of his voyage—the first ever made by a white man—down that portion of the Mississippi, they marched slowly, lifting their pipes to the sun, as if offering them to him to smoke. They also make a similar offering to him when they wish to obtain calm, or rain, or fair weather.§ Among the Ottawas, of Michigan, prayers were offered to the sun, and tobacco was burned as a sacrifice to the same deity.‖ Indeed, the use of tobacco as an offering

* Purchas *Pilgrims*, vol. IV, p. 1868: London, 1625.

† *Voyages des Hurons*, p. 226: Paris, 1632. "Soleil qui ils ont adoré et qui a toujours été l' object constant de leur culte, de leurs hommages et de leur adoration:" *Nouvelle Relation* de la Gaspesie, p. 166: Paris, 1691. "Ils appellent le Soleil Jesus. - - - De la vient que quand nous faisons nos prière il leur semble que comme eux nous addressons nos prière au soleil:" *Relation de la Nouvelle France en l' année* 1626, p. 4: Quebec, 1858.

‡Father Marquette, in *Relation*, 1670, p. 90. Charlevoix, *Letters*, p. 210: London, 1763. "Some of the savages will confess - - - that the Sun is God:" Hennepin, *Voyage into a Newly Discovered Country*, p. 65: London, 1698. Father Marquette, in *Discovery and Exploration of the Mississippi*, p. 54.

§ *Relation* of Father Marquette (A. D. 1678), *l. c.*, pp. 21-22-35: New York, 1852. The Sioux, though belonging to a different linguistic family, and living on the other side of the Mississippi, had similar customs. According to Hennepin, who is not always good authority, but who may, I think, be followed in this instance, "they offer also to the Sun the best Part of the Beast they kill; - - - also the first Smoak of their Calumets, - - - which makes me believe they have a religious veneration for the Sun:" *New Discovered Country*, etc., vol. I, p. 140: London, 1698. Compare on this point Schoolcraft, *Indian Tribes*, vol. III, pp. 226-7, and Nuttall, *Arkansa Territory*, p. 276: Philadelphia, 1821.

‖ Un viellard des plus considerables de la Bourgade fait fonction de Prêtre; il commence par une Harangue étudiée qu' il addresse au Soleil; - - - il declare tout haut qu 'il fait ses remerciemens à cet astre, de ce qu 'ilé a éclairl' pour tuer heureusement quelque bête: il le prie et l' exhorte par ce festin a lui continuer les soins charitables qu 'il a de sa famille. Pendant cette invocation, tous les conviés mangent Jusqu' au dernier morceau: apres quoi un homme destiné a cela prend un pain de Petun, le rompt en deux et le jette dans le feu. Tout le monde crie pendant que le petun se consume, et que la fumée monte en haut: et avec ces clameurs termine le sacrifice:" Lafitau, vol. II, p. 131. "Sacrifice to the Sun:" La Hontan, vol. II, p. 32. *Relation en l' année 1667*, pp. 7, 11: Quebec, 1858.

seems to have been universal among the American Indians. Charlevoix* and Lafitan† both speak of the practice as being general, and their statements are confirmed by writers who have left us accounts of the rites and ceremonies as practiced by the different tribes. Thus Hariot, who wrote in the latter part of the sixteenth century, tells us that this plant was held in such esteem by the Indians of Virginia that they imagined that their gods were pleased when it was offered to them. It was for this reason that from time to time they built sacred fires, on which they burned this plant as a sacrifice. He also adds, that when they are surprised by a tempest they scatter it upon the water or throw it up in the air; and they also put it in their new nets in order to insure success in fishing.‡ There was also something of a religious character in the practice common among all the Indian tribes of the United States of smoking the calumet as a preliminary to any treaty, or bargain, or agreement of any kind. According to Charlevoix the Indians claimed to have "received the calumet from the Panis, to whom it had been given by the sun, and they held it so sacred that there was probably no instance of an agreement made in this manner that was ever violated. They believed that the Great Spirit would not leave such a breach of faith unpunished. - - - In trade, when an exchange has been agreed upon, a calumet is smoked in order to bind the bargain, and this makes it in some manner sacred. - - - There is no reason to doubt that the Indians, in making those smoke the calumet with whom they wish to trade or treat, intend to call upon the sun as a witness and in some fashion as a guarantee of their treaties, for they never fail," so the old chronicler tells us, "to blow the smoke toward that star."§

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* "They make to all these Spirits different sorts of offerings, which you may call, if you please, sacrifices. They throw into the Rivers and the lakes *Petum*, Tobacco, or birds that have had their throats cut, to render the God of the waters propitious to them. In honor of the Sun, and sometimes also of the Inferior Spirits, they throw into the Fire Part of every Thing they use, and which they acknowledge to hold from them. It is sometimes out of Gratitude, but oftener through Interest:" *Letters* p. 252.

† "Il est certain que le Tabac est en Amerique une herbe consacré a plusieurs exercices, et a plusieurs usages de la Religion:" *Moeurs des Sauvages Ameriquains*, vol. II, p. 133, *et seq.*, also vol. I, p. 179. Schoolcraft, vol. VI, note to p. 109, says: "The Nicotiana was smoked and offered as incense to the Great Spirit by all the northern tribes."

‡ Hakluyt, *Voyages*, vol. III, p. 330: London, 1810. Compare Champlain, p. 208: Paris, 1632. Sagard, *Voyage des Hurons*, vol. I, p. 151: Paris, 1865. Bartram, p. 479. *Relation en l' année 1637*, pp. 108-144.

§ Charlevoix, *Letters*, pp. 133, *et seq.*: London, 1763. Bartram, in his MSS. quoted in *Serpent Symbol*, p. 69: New York, 1851, says of the Creeks: "They pay a kind of homage to the Sun, Moon, and Planets. - - - They seem particularly to reverence the Sun as the symbol of the Power and Beneficence of the Great Spirit, and as his minister. Thus at treaties they first puff or blow the smoke from the great pipe or calumet towards that luminary; and they look up to it with great reverence and earnestness when they confirm their talks or speeches in council as a witness of their

If now we turn to the tribes of the Huron-Iroquois stock, we shall find that the sun was not less an object of worship. In the Relation of 1648 we are told that they invoked him as a judge of their sincerity, who saw into the depth of all hearts, and who would punish the perfidy of those who broke their faith, or failed to keep their word. Lafitau states positively that Areskoui and Agreskoué (the difference is said to be linguistic), the war god of the Hurons and the Iroquois, was but another name for the sun, "who was their Divinity as he was that of all the Americans."* La Hontan confirms the fact of their worship of this luminary, and says that, when "asked why they adore God in the sun rather than in a tree or a mountain," their answer is that they choose to admire the Deity in public, pointing to the most glorious thing that nature affords.† According to Lafitau‡ they had no temples, and did not keep up a perpetual fire; at least there was not a vestige left of any such building in his time, and no mention of any such institution in any of the "Relations" of the Jesuit Fathers. This however can hardly be considered decisive of the point, since we are given to understand that these tribes had lost many of their religious customs;§ and in this very connection are assured that the fire on their hearths took the place of an altar, and that as was the case among the Creeks and Cherokees, their "council houses served them as temples."‖ Bearing upon this point, and as an evidence of the identity of the religious rites and ceremonies everywhere prevalent, we may note that once a year they were accustomed to put out all the fires of the tribe and to rekindle them with fire supplied by the priests,¶ as was the case among the Southern tribes. Morgan it is true does not mention this custom in his account of the Iroquois festivals, but he describes the practice of "stirring the ashes on the hearth," which took place at their New Year's Jubilee,** and it is possible that there may have been some connection between the two.

Among their sacrifices there were some that seem to have been peculiar to the northern nations. Thus, for instance, although the dog was a favorite article of food among the tribes both north and south of the Ohio, and was not unfrequently offered as a sacrifice, yet I do not find that anywhere else they "hung him up alive on a tree by the hind feet and let him die there raving mad."†† They were in the habit of ex-

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contracts." "Osages smoke to God or to the Sun:" Nuttall, *Arkansa Territory*, p. 95: Philadelphia, 1821.

* *Moeurs des Sauvages Ameriquains*, vol. I, p. 132–206: Paris, 1724.

† La Hontan, *Voyages* vol. II, pp. 22 and 33: London, 1703.

‡ Lafitau, vol. I, p. 165.

§ *Ibid.*, vol. I, pp. 282–341.

‖ *Ibid.*, vol. I, p. 167.

¶ Schoolcraft, *Notes on the Iroquois*, p. 85: New York, 1846.

** Morgan, *League of the Iroquois*, p. 207, *et seq.*: Rochester.

†† Lafitau, vol. I, p. 180, says that this custom prevailed among the Montagnais and other Algonquin tribes to the north, but Charlevoix makes no such distinction. He

posing, on the tops of their cabins, strings and necklaces of beads, bunches of corn, and even animals, which they consecrated to the sun.* They also made burnt offerings to the same divinity of corn, of animals taken in the chase, and of tobacco or other plants that served them in its place,† in much the same manner as was done among the tribes belonging to the Algonquin and Appalachian families. In their war sacrifices the Iroquois take "the leg of a deer or bear, or some other wild beast, rub it with fat, and then throw it on the fire, praying the sun to accept the offering, to light their paths, to lead them and give them the victory over their enemies, to make the corn of their fields to grow, to give them a successful hunt or fish."‡ They also had their annual festivals, among which that of the green corn was one of the most important. It was celebrated when the corn became fit for use, usually lasted several days, and was the counterpart of the feast of the Busk, as observed among the Indians of the Gulf States. Morgan paints, with a loving hand, the simple ceremonies with which the Iroquois of later times were wont annually at this festival, to return thanks to the Great Spirit for his bounty, and to solicit a continuance of his favor and protection. It was at this time that they offered a sacrifice of tobacco, believing that they could communicate with him through its incense;§ and in their prayers they returned thanks "to our mother, the earth, which sustains us; - - - to the corn, and to her sisters, the beans, and the squashes, which give us life; - - - to the sun, that he looked upon the earth with a benificent eye, and lastly to the Great Spirit, in whom is embodied all goodness, and who directs all things for the good of his children."‖

Thus far we have been considering the religious rites and customs of the different tribes of Indians that occupied the eastern portion of the Mississippi Valley, and we have seen that there was a general sameness pervading them, and that all grew out of, or were connected with, the worship of the sun. If now we turn from this theme and examine into their myths, we shall find that, though the path be different, yet it leads to the same result.

Accepting the Natchez as a type of the group of Southern tribes, we are told that, ages ago, a child of the sun, who saw and pitied their disorganized condition, came down with his wife for the purpose of establishing order and instituting religious rites and ceremonies among them. He gave them certain precepts—political as well as religious—

asserts it of all the Indians of Canada. See *Letter*, p. 252. Compare *League of the Iroquois*, pp. 207 *et seq.*, and McKenzie, *History of Fur Trade*, quoted in p. 121 of *Serpent Symbol*.

* Charlevoix, *Letters*, p. 252. Lafitau, vol. I, p. 180.

† Lafitau, vol. I, p. 179.

‡ *Ibid.*, vol. I, pp. 208, 209: Paris, 1724.

§ *League of the Iroquois*, pp. 198, 217: Rochester, 1851.

‖ *Ibid.*, p. 203, 204.

for their better government; and having conducted them into a better land, he became at last, after much solicitation, their sovereign. It was through him that the Natchez claimed their descent from the sun, and from him they took the official title of their chief.. This is the myth as told by Du Pratz,* and though, unfortunately, the religious precepts which are said to have been inculcated bear a most suspicious, and, under the circumstances, absurd likeness to the Ten Commandments, yet it is possible that the rest of the story may be genuine.

Among the Algonquin tribes we are on firmer ground. Here we have the old story of "the conflict between light and darkness, in which the former, personified under the name of Michabo, is the conqueror. He is the giver of light and life, the creator and preserver, - - - and in origin and deeds he is the not unworthy personification of the purest conception they possessed of the Father of All. To him, at early dawn, the Indian stretched forth his hands in prayer; and to the sky or the sun as his home"† or, it may be added, as his representative, or as this deity himself, he offered the first whiff of his morning pipe.

Among the Huron-Iroquois we find the same myth, though under different names. With them the contest was between Ioskeha and Tawiscara, names which, according to Brinton, signify, in the Oneida dialect, the White one and the Dark one. "They were twins, born of a virgin mother, who died in giving them life. Their grandmother was the moon, called by the Hurons Ataensic. - - - The brothers quarreled, and finally came to blows, the former using the horns of a stag and the latter the wild rose. He of the weaker weapon was very naturally discomfited and sorely wounded. Fleeing for his life, the blood gushed from him at every step, and turned into flint stones. The victor returned to his grandmother, and established his lodge in the far east, on the borders of the great ocean whence the sun comes. In time he became the father of mankind, and the special guardian of the Iroquois. The earth was at first arid and sterile, but he destroyed the gigantic frog which had swallowed the waters, and guided the torrents into smooth streams and lakes. The woods he stocked with game; and having learned from the tortoise how to make fire, he taught his children, the Indians, this indispensable art."‡ "Without his aid," says Father Breboeuf, "they did not think their pots would boil. - - - He it was who gave them the corn which they ate, and who made it grow and ripen; if their fields were green in the spring-time, if they

* *History of Louisiana*, vol. II, p. 175 *et seq.*, and London, 1763.

† Brinton, *Myths of the New World*, p. 183: New York, 1876. Compare Schoolcraft, *Indian Tribes*, vol. V, pp. 402–417. *Relation de la Nouvelle France en l' année 1633–1634*, pp. 16 and 13 respectively: Quebec, 1858. Lafitau, vol. I, pp. 126–145: Paris, 1724. La Potherie, vol. II, chapter i: Paris 1753.

‡ Thus far I have copied Brinton, *Myths of the New World*, p. 183, who has followed Father Breboeuf, *Relation de la Nouvelle France en l' anneé*, 1636, seconde partie, chap. i: Quebec, 1858. In what follows I prefer to stick to the text of the old Father.

gathered plentiful harvests, and their cabins overflowed with grain, they owed thanks to no one save Ioskeha,"* the sun.†

This completes our brief examination into the religious belief and customs of the American Indians living east of the Mississippi and south of the Great Lakes. In it we have glanced rapidly at their myths and their beliefs, and the rites and ceremonies to which these gave rise, and we have found that each line of investigation led to one and the same result. In view then of this uniformity, and of the overwhelming area of direct evidence that has been offered on the point, I do not think it is overstepping the bounds of moderation to claim, with the old chronicler, that within the limits named, "the American Indians, so far as known, without the exception of a single tribe, worshipped the sun."‡

## III.—THE INDIANS AS MOUND-BUILDERS.

Thus far in the course of this investigation my position has been rather a negative one. It is true that an effort has been made to show, and it is believed with some measure of success, that the red Indian of historic times was both an agriculturist and a worshiper of the sun, and that hence, even according to the admission of those who hold a contrary opinion, there are no reasons, *a priori*, why he could not have erected these works. This is unquestionably a step in the right direction; and with this point gained, I might well afford to rest the argument. It would not however be by any means decisive of the question as to the origin of these structures, since the fact that an Indian might have built them does not justify us in concluding that he actually did do so. To fill up as far as possible the gap that separates the ability to do a certain piece of work from its actual performance, it will be necessary in this case to abandon the seemingly negative position hitherto occupied, and to inquire whether there is any evidence that the Indian has at any time constructed works of the same character, though perhaps not of the same size as the largest of those found in the Ohio Valley. If it can be shown that he has done so it is believed that it will justify us in ascribing all these structures to his agency, for the reason that these mound centers, with scarcely a single

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* "Ils tiennent aussi que sans *Iouskeha* leur chandiere ne pourroit bouillir, - - - a les entendre, c' est Iouskeha qui leur donne le bled qu' ils mangent, c' est luy qui le fait crostre et le conduit a maturité; s' ils voyent leurs campagnes verdoyantes au Printemps, s' ils recueillent de belles et plantureuses moissons, et si leurs cabanes regorgent d' espics, ils n'en ont l'obligatión qu'a Iouskeha:" *Relation de la Nouvelle France en l' anneé* 1636, p. 103: Quebec, 1858.

† "Mais pour retourner à *Aataentsic* et *Iouskeha*, ils tiennent que *Iouskeha* est le Soleil, et *Aataentsic* la Lune, et toute-fois leur cabane est situeé au bout de la terre:" *Relation*, 1636, p. 102: Quebec, 1858.

‡ "Le Soleil est la Divinité des Peuples de l'Amerique, sans en excepter aucun de ceux qui nous sont connus:" Lafitau, *Moeurs des Sauvages Ameriquains*, vol. 1, p. 130: Paris, 1724.

exception, can be proven to have been at some time the seats of mound-building Indians, and because never, so far as we know, have they been held even temporarily by any other race of people previous to the arrival of the whites.

In pursuing this branch of our inquiry the only method open to us is to proceed by comparison. For obvious reasons we can never know the particular individuals by whom these works were erected, nor can we, except in a few cases, even hope to do more than approximate the time when they were built. All that can be accomplished in the present state of our knowledge is to show by a comparison of these remains with similar works that are known to have been erected by the modern Indians that there are no such differences between them as would authorize the inference that they were built by different peoples, or by the same people in different stages of civilization.

To institute a comparison of this character seems like a very simple matter, and it would be so if there were any way of establishing a hard and fast line of demarcation between the works of the Indians and those of the so-called mound-builders. Unfortunately however or perhaps it might be more correct for me to say fortunately, nothing of the kind can be done; for though, as a matter of fact, the mounds and earthworks of the Mississippi Valley do vary indefinitely in size, shape, location, grouping, and possibly in many other respects, yet these are all differences of degree and not of kind; and however great the distance between the extremes in any one of these particulars, it is not of such a radical character as to indicate a difference in the civilization of the people who constructed the works. Given time and an indefinite supply of laborers, and there is no reason why the people who built one might not have built any and all of them. The simple manual labor necessary to their construction was essentially the same in every case, the only question being as to the amount. That this is so is evident from the fact that when considered solely with reference to the kind and amount of this labor, these works are found to grade into each other by such imperceptible stages that admitting them to have been erected by different peoples, it is impossible to say where the work of one ended and that of the other began. This statement has I know met with more or less opposition, and it is quite likely that in the future, as in the past, we shall be told of the existence of some line of demarcation between them, though it is possible that the attempt to fix and define it will not meet with any better success than has crowned former efforts in the same direction. Size, shape, and probable use have at different times been thought to furnish a key to the mystery; and either singly or together they are still occasionally made to do duty in this capacity; but with all due deference to those who so pertinaciously seek for differences where none exist, it may be said, without fear of successful contradiction, that thus far not one of these so called distinguishing features has been able to stand the test of intelligent

criticism; and that to-day it looks very much as if it would be necessary to fall back upon what a recent writer terms "indefinable marks" and "resemblances that cannot be described," in order to find a foundation for the theory of a difference in the character of these works, and consequently in the civilization of the people who built them. Indeed, the advocates of this theory do not agree among themselves as to where this line should be drawn; and from the very nature of the case it may well be doubted whether it is possible for them ever to attain any very great degree of harmony. The mound-builders are at best a mythical people, who owe even their imaginary existence to the necessity of accounting for a state of affairs that is in great part assumed; and of course any standard by which to judge the works they are supposed to have executed must vary with the fancy of the writer or the exigencies of the argument. But even if this were not the case, and there were no subjective obstacles in the way of uniformity of opinion upon this vital point, it would still be impossible to establish any test or standard, for the reason that, except in the fact that a large majority of the mounds and embankments "are made of earth simply heaped up, with little or no care in the choice of material, and none at all in the order of deposit,"* there are no two of them that are alike; and without the presence of some conformation that is at least constant, it is of course idle to speak of a type or standard.

To make this point clearer, let us glance at these remains as they have come down to us, and putting aside, as far as possible, all theories and speculations as to their origin and use, let us question them as to the civilization of which they are the silent witnesses. To this end, it will be advisable to discard, as far as may be consistent with clearness, the descriptive nomenclature that has been used in the classification of these works, and to adopt one that will be less productive of false and erroneous ideas as to the object or purpose for which many of them were intended. As an instance of the errors arising from this source, take the term "sacred inclosure," which has been applied to a class of works that is usually found upon the broad and level river terraces, and is composed of mounds and embankments or inclosures, sometimes standing alone, but more frequently grouped together in a more or less complicated manner. This term has been long in use, and by a sort of prescriptive right is sometimes regarded as describing accurately the character of the works to which it has been applied, when in point of fact it does nothing of the kind. A few of these inclosures may possibly owe their origin to a religious sentiment, but of the large majority of them it may be safely said, in view of recent investigations, that they were simply fortified villages. Self-protection was the primary object of the people who lived behind these walls, and except in the single fact that some of the truncated mounds occasionally found associated

* Bancroft, *Native Races of the Pacific States*, vol. IV, p. 766: New York, 1875.

with them may have been the sites of rude mud temples, there is not a particle of evidence to show that they had anything to do with any religious rite or custom whatsoever. Indeed, if it be admitted that the mound-builder belonged to a race separate and distinct from the Indian, it can not be conclusively shown that he had any religion at all. What little evidence there is bearing upon the point is drawn from analogy, and singularly enough is based upon the fact that the Indians of the Southern States, from Florida to Missouri, erected just such mounds as sites for their temples.* Unfortunately however for the analogy, these same Indians were in the habit of placing the cabins of their chiefs upon precisely similar mounds, which were also built especially for the purpose.† This fact alone is sufficient to invalidate any conclusion as to the religious character of these structures; and of course any inference as to the object or purpose of the inclosures in which they are sometimes found, based upon this conclusion, must fall with it. But even if these works were all that is claimed for them, it is difficult to understand how this fact could be construed into an argument in favor of the theory that these truncated mounds, which are everywhere identical in form and in the probable uses for which they were intended, could have been the work of two different peoples, or of the same people in different stages of civilization, though its importance as a link in the chain of evidence that points to the identity of the Southern Indians with the mound-builders is at once apparent.

Returning from this long digression, and bearing in mind the caution as to the misleading character of the terms used in these investigations, let us resume the thread of our inquiry, and divesting these remains of the glamour that attaches to them as the work of an extinct people, let us endeavor to see them as they are, and to interpret as far as may be the story they have to tell.

Speaking in a general way, the Mississippi Valley system of earthworks may be said to embrace all that region that lies between the Great Lakes on the north and the Gulf of Mexico on the south, and to be bounded on the west by the tier of States that lines the western bank of the Mississippi, and on the east by a line drawn through the middle of the States of New York, Pennsylvania, and Virginia, and extending southwardly so as to include the greater part of the two Carolinas and the whole of Georgia and Florida. It is true that similar works are found outside of these limits, but for my present purposes it will not be necessary, except in one or two instances, to travel beyond the bounds here prescribed. Throughout the whole of this region these remains are more or less abundant, though different forms of mounds

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* See *ante*, note § on p. 540.

† Biedma and Knight of Elvas, in *Hist. Coll. of Louisiana*, part II, pp. 105 and 123: La Vega, *Conquête de la Floride*, pp. 136 and 294: A la Haye, 1735. Herrera, vol. VI, pp. 5 and 6: London, 1740. La Harpe and Le Petit, in *Hist. Coll. of Louisiana*, part III, pp. 106 and note to p. 142. Du Pratz, *History of Louisiana*, vol. II, p. 188: London, 1763.

and earthworks seem to prevail in different sections, as, for instance, the animal mounds in Wisconsin, the inclosures in Ohio, and the truncated mounds in the States farther to the south. All kinds however are represented in the Ohio Valley, and it is probably safe to say that, within that basin, they are more numerous, of larger size, and more complicated patterns than can be found elsewhere in the United States.

Taken as a whole, they may be roughly divided into two grand divisions—mounds and embankments,—and these can again be sub-divided into numerous groups. Beginning with the embankments or inclosures, we find that they are generally of earth—rarely of stone,—and that they are situated on the level river terraces, or else occupy the tops of hills or other naturally strong positions. According to their situation, they have been divided into works of defense and sacred inclosures, or as I prefer to call them, hill-forts and fortified villages The former of these almost always followed the outlines of the hill, and are hence more or less irregular in shape. In some of them the whole top of the hill is inclosed by a wall, whilst in others only the more exposed points are so defended. The fortified villages are usually found on a level plain—one of the river benches or terraces being generally selected. They are of various sizes and shapes, though the square and circle predominate, and are often found united in a seemingly arbitrary manner. The height of the wall around the inclosure, measured from the bottom of the ditch that usually accompanies it, varies from a few feet up to 30. In many instances it is now, and must always have been, too insignificant to offer any serious obstacle to an attacking force; and this has given rise to the suggestion that these embankments were formerly surmounted by stockades, as was the case with the villages of the recent Indians. Without stopping now to inquire into the probability of this explanation, it is sufficient to say that there cannot be the slighest doubt as to its truth in regard to some of them. Brackenridge* states the fact positively, and Atwater tells us that half-way up, on the outside of the inner wall that surrounded the circle, or as he calls it the "round fort," which formed a part of the large and complicated series of works that once occupied the site of the present town of Circleville, Ohio, "there is a place distinctly to be seen where a row of pickets once stood, and where it was placed when this work of defense was originally erected." † In point of size these works varied greatly. Some of the smaller circles—probably the ruins of mud lodges or tem-

* *Views of Louisiana*, pp. 21 and 182–3: Pittsburg, 1814.

† *Archæologia Americana*, vol. I, p. 145: Worcester, Mass., 1820. As these works will be referred to hereafter, I add a description from the same book, pp. 141–2: "There are two forts which are joined together, one being an exact circle, the other an exact square. The former is surrounded by two walls, with a deep ditch between them. The latter is encompassed with one wall, without any ditch. The former was 69 rods in diameter, measuring from outside to outside of the circular outer wall; the latter is exactly 55 rods square measuring the same way. The walls of the circular fort were at least 20 feet in height, measuring from the bottom of the ditch,

ples similar to those described as having existed among the Southern Indians,* and which may still be seen among some of the tribes of the Upper Missouri†—are not more than 50 feet in diameter, whilst the groups, or series of works in which the different forms are united, not unfrequently covered hundreds of acres, or, as was the case with the works at Newark, Ohio, were scattered about over an area of 2 miles square.‡

The situation of the ditch with reference to the wall was a matter in which there was but little if any uniformity, it being sometimes on one side of the wall and sometimes on the other. At one time this feature was thought to furnish a criterion by which to judge the character of the work, and Mr. Squier quotes approvingly English authorities to the effect "that the circumstance of the ditch being within the vallum is a distinguishing mark between religious and military works."§ This position however does not hold good with regard to earth-works in the United States, since it is matter of record that in some of the stockaded forts of the recent Indians the ditch was on the inside of the wall, whilst in others there was a ditch on each side.‖ Indeed, when we con-

before the town of Circleville was built. The inner wall was of clay, taken up probably in the northern part of the fort where was a low place, and is still considerably lower than any other part of the work. The outside wall was taken from the ditch which is between these walls, and is alluvial, consisting of pebbles worn smooth in water, and sand, to a very considerable depth, more than 50 feet at least. The outside of the walls is about 5 or 6 feet in height now; on the inside, the ditch is, at present, generally not more than 15 feet. They are disappearing before us daily, and will soon be gone. The walls of the square fort are, at this time, where left standing, about 10 feet in height. There are eight gateways or openings leading into the square fort, and only one into the circular fort. Before each of these openings was a mound of earth perhaps 4 feet high, 40 feet perhaps in diameter at the base, and 20 or upwards at the summit. These mounds for 2 rods or more are exactly in front of the gateways, and were intended for the defense of these openings."

* Joutel, in *Hist. Coll. of Louisiana*, part I, p. 148. Among the Alachua (Floridian) Indians, we are told by Bartram that "their dwellings stand near the middle of a square yard, encompassed by a low bank, formed with the earth taken out of the yard, which is always carefully swept:" *Travels through Florida*, p. 192.

† Catlin, *North American Indians*, vol. I, p. 81: London, 1848. In the Peabody Museum of American Archæology and Ethnology at Cambridge, Mass., there is a model of one of these mud lodges, such as is now in use among the Omahas.

‡ *Ancient Monuments of the Mississippi Valley*, p. 67.

§ *Ibid.*, chap. III, note to p. 47.

‖ Charlevoix, *Histoire de la Nouvelle France*, vol. IV, p. 156: Paris, 1744. Schoolcraft, *Travels in the Mississippi Valley*, p. 129. Catlin, *North American Indians*, vol. I, p. 81: London, 1848. In the town of Medford, Mass., near Mystic Pond, there was a "Fort built by their deceased King, in manner thus: There were pools some thirtie or fortie foote long, stucke in the ground as thicke as they could be set one by another, and with these they enclosed a ring some forty or fifty foote over. A trench breast high was digged on each side; one way there was to goe into it with a bridge; in the midst of this Pallizado stood the frame of a house wherein being dead he lay buried. A myle from hence we came to such another," etc.: Mourt's *Relation*, p. 126: Boston, 1865.

sider the nature of the position to be defended, and bear in mind the effective use of rifle pits in modern warfare, it may well be doubted whether the inside is not, under certain conditions, the proper place for it.

In the material of which they were made these embankments varied but little. As has been well said by H. H. Bancroft,* "they are of earth, stones, or a mixture of the two, in their natural condition, thrown up from the material which is nearest at hand. There is no instance of walls built of stone that has been hewn or otherwise artificially prepared, of the use of mortar, of even rough stones laid with regularity, of adobes or earth otherwise prepared, or of material brought from any great distance. The material was taken from a ditch that often accompanies the embankment, from excavations or pits in the immediate vicinity, or is scraped up from the surface of the surrounding soil. There is nothing in the present appearance of these works to indicate any difference in their original form from that naturally given to earth-works thrown up from a ditch, with sides as nearly perpendicular as the nature of the material will permit. Of course any attempt on the part of the builders to give a symmetrical superficial contour to the works would have been long since obliterated by the action of the elements; but nothing now remains to show that they attached any importance whatever to either material or contour. Stone embankments are rarely found, and only in localities where the abundance of that material would naturally suggest its use. In a few instances clay has been obtained at a little distance, or dug from beneath the surface."

Turning now to our second grand division—the mounds,—we find them composed of earth and stone, and varying in location, size, shape, and contents. Divided according to their form, they may be classed as—

First. "Temple" or truncated mounds, which as their name indicates are truncated cones, usually with graded ways to their tops, and in some instances with terraced sides. Their bases are of different forms, being indifferently either round, oval, square, or oblong; but whatever may have been their differences in these respects, they were all alike in having flat or level tops, which were no doubt used as sites for their rude temples, or the cabins of their chiefs. In size, they varied from a height of 5 feet to 90, and from a base of 40 feet in diameter to one covering an area of 12 acres.† Like the embankments, they are simply heaps of earth, some of them, it is true, of immense size, but all of them thrown up without much "care in the choice of material, and none at all in the order of deposit."

Second. The next class is composed of the "animal mounds," or mounds in which the ground plan is more or less irregular, and is

* *Native Races of the Pacific States*, vol. IV, p. 753.

† See the account of the Cahokia Mound in 12th *Annual Report of the Peabody Museum.*

thought to resemble animals, birds, and even human beings, though it is admitted that this resemblance is often imaginary, and that there is no evidence that the builders of these works intended to copy any such forms. Indeed, Lapham,* to whom we are indebted for the most satisfactory account of these mounds that we possess, finds it necessary, on more than one occasion, to caution his readers against blindly accepting these resemblances, and frankly says that in some cases appellations, like that of "Lizard Mound," were given for the sake of convenience, and without pretending that they were actually intended to represent that animal.† According to the same author, as summarized by Bancroft, these mounds vary in height from 1 to 6 feet, and their dimensions on the ground are quite large. Thus "rude effigies of human form are in some instances over 100 feet long; quadrupeds have bodies and tails each from 50 to 200 feet long; birds have wings of a hundred feet; lizard mounds are 200 and even 400 feet in length; straight and curved lines of embankments reach over a thousand feet, and serpents are equally extensive." Mounds of this class are common in Wisconsin, and are also found in Ohio and Georgia. They are not burial mounds, though they are not unfrequently grouped with conical mounds that inclose human remains, as they are also with embankments and inclosures,—the grouping being always without any apparent order. They are usually constructed of earth, stones being but rarely used, except perhaps in Georgia, where the two bird-shaped mounds described by Col. C. C. Jones are built entirely of that material.‡

Third. The third and last class of mounds consists of the simple conical tumuli that are scattered about over this whole area and are far more numerous than all the others combined. So far as outward appearance is concerned they are generally round or oval, though other forms are not unfrequent. They vary in height from a few inches to 70 feet,§ and in diameter from 3 or 4 feet to 300. It is probable however that a height of from 3 to 30 feet and a diameter ranging at the base from 15 to 50 feet would include a large proportion of them. Although so alike in form, these mounds differ widely in location, and, as we shall see later on, in their contents. They are found on the tops of the highest hills and in the lowest river valleys; they stand alone or in groups, or in connection with hill-forts or fortified villages, of which they evidently formed component parts. In the material of which they are built, as well as in the manner of their construction, they do not differ from the embankments and from other mounds. A

* Antiquities of Wisconsin, in vol. VII of the *Smithsonian Contributions to Knowledge*, pp. 14, 24, 130, etc. See also *Anc. Mon. of the Mississippi Valley*, p. 130, in which Mr. Squier speaks of a mound that "may have been intended to represent a bird, a bow and arrow, or the human figure."

† *l. c.*, note to p. 9.

‡ *Smithsonian Report* for 1877, p. 278.

§ *Anc. Mon. Miss. Valley*, pp. 5 and 168.

large majority of them are simply heaps of earth, though stone mounds or cairns are quite common, and in Florida they are sometimes composed almost entirely of shells. As a rule, they are homogeneous in structure, though occasionally in the Ohio Valley, and especially along the Scioto River, there are a few that were regularly and intentionally stratified.*

This is believed to be a fair statement of all that is known of the mounds, considered simply as mounds, and without any regard to their contents, or to what is known of them historically. It is taken almost literally from Bancroft,* whom I have chosen to follow, for the reason that his summary of the results of the explorations of Squier, Lapham, and others is just and comprehensive, and because, in a matter of this importance, it seemed to me desirable to distrust my own judgment and to accept the statement of one who can not be accused of sharing in the conclusions to which I have been most unexpectedly driven.

As a result of this rapid glance at the story of these remains, when told by themselves, it will be seen that although they differ widely in form, size, and the evident use for which they were intended, yet they are, primarily, nothing but heaps of earth, stones, or a mixture of the two, thrown up into the form of mounds and embankments. A child at play on a pile of sand performs on a small scale, and for his amusement, the very same kind of labor as that involved in their erection; and the beaver and the white ant, in building their dams and nests, show a degree of development—a faculty of adapting means to an end—but little if any inferior to that displayed by the mound-builder, when judged by the same standard. Indeed, we are told that the beaver dams and washes of Wisconsin sometimes bear a very close resemblance to the so-called serpent mounds, and to the excavations made by the Indians in search of lead and other ores;† whilst as a matter of fact, the ant hills of Africa, in point of relative size,‡ and in the architectural knowledge and engineering skill displayed in their construction, are quite equal to any earthwork in the Ohio Valley. In saying this, it must not be supposed that there is any intention of disparaging the works of the mound-builders. Unquestionably some of them are of great size, and exhibit an immense amount of patient toil and perseverence; but beyond this they tell us little or nothing. Nowhere, either in laying them out, or in the manner in which the dead were sometimes buried in them, can be found any such adherance to the principle of orientation as would authorize the inference that the people who built and buried in them had advanced beyond the merest rudiments of astronomical knowledge; and as for the mathematical skill displayed in the construction of their squares and circles, anyone

* *Native Races of the Pacific States*, vol. IV, chap. xiii.

† *Antiquities of Wisconsin*, *l. c.*, note to p. 11.

‡ Some of the hills of the so-called white ants of Africa are 25 feet high, and honeycombed with galleries.

who has ever aided in fencing a western farm knows that it is a comparatively simple matter to "run" a straight line, especially if it be as broad as most of these embankments; and that consequently squares as large and with angles as "perfect" as any of those in the Ohio Valley, can be constructed with the aid of three straight sticks and a moderately good eye. The circles might perhaps give a little more trouble; but even they are not beyond the compass of a boy with a string. Mr. Squier himself admits that it is possible to construct them of considerable size without the aid of instruments, though one over a mile in circumference would, he thinks, offer serious obstacles.* In a word, the labor involved in the erection of these works was purely manual, and perfectly homogeneous. It did not even necessarily imply the use of mechanical aids of any kind, though it is probable that the rude stone hoe or spade and a basket—one to loosen the earth, and the other to transport it—were both employed; and these (be it remembered) were within reach of every Indian family east of the Mississippi and south of the Great Lakes.

The fact then as to the character of this labor being as stated, it would seem to follow that a people who could have erected one of these works, be it a mound or an embankment, might have built any and all of them; and of course, if it can be shown that the red Indian has, within the historic epoch, thrown up mounds 5 or 10 feet high, and of proportionate size, there can be no reason why, given time, of which he had an unlimited supply, or an increased number of workmen, he could not have made them ten times as large had he been so inclined. To deny this involves the necessity of showing that there existed, in mound-building, some point beyond which the efforts of the Indian could not go—some limit to the number of baskets full of earth he might bring—and this will scarcely be undertaken by the hardiest advocate of the theory of the two civilizations. Indeed, it is only necessary to put the matter in this broad light, to ask where it is proposed to run this line of demarcation, and how it was found, in order to show the absurdity of any attempt to set up a standard that will enable us to say, definitely, whether any given earthwork was built by the recent Indians or by the so-called mound-builders.

With this fact clearly understood, we are now ready to take up the evidence that points to the red Indian of modern times as the builder of these works; and by way of beginning, let us look into the truth of the oft-repeated statement that he had no tradition as to their origin, and the purposes for which they were erected. So far as my immediate argument is concerned, this is to some extent a work of supererogation. Tradition is at best but an unsafe guide, and even if it were

*Anc. Mon., p. 61. Bearing upon this point is the statement of Miss A. C. Fletcher, that the Ogalalla Sioux, when marking out the ground for the sun dance, raise up a pole in the center, and then, with a rawhide cord as a radius, draw a circle of the required size, say from 200 to 300 feet in diameter.

not, the fact that the Indians could not give any account of these structures would carry but little if any weight, for the reason that it is negative evidence pure and simple, and as such must give way to the well-authenticated instances of mound-building among the Natchez and other historic tribes. Upon this point there can be no difference of opinion, and though it clearly shows the worthlessness of tradition as the basis for an argument in the present discussion, yet the statement as to the absence of all accounts of the origin of these works is so often repeated, and with such seeming confidence, that the investigation would be incomplete without some inquiry into its truth. Especially is this so in view of the fact that like all wholesale generalizations it has a certain foundation in truth, though this is believed to be entirely too slight to justify us in accepting the statement in the shape in which it has come down to us. That certain Indians—the number is immaterial—were without any tradition upon the subject of these mounds is extremely probable; and if the early writers had confined themselves to a statement of this fact, there would have been no question as to its acceptance. But when generalizing (as was too often their wont) from the few instances that came under their observation, they tell us that "the Indians" or that "certain tribes" were equally ignorant, then it is time to call a halt, and inquire into the validity of the evidence upon which the statement rests. To do this thoroughly involves no little labor. Trustworthy authorities must be examined—the more the better,—and if they fail to bear out the general conclusion, as will almost always be found to be the case, there is no alternative but to so modify this conclusion as to bring it in accord with the newly-discovered evidence. As an instance of the good results that sometimes follow this method of interpreting the old chroniclers, take the assertion of the younger Bartram that "the Cherokees are as ignorant as we are, by what people or for what purpose these artificial hills were raised."* He is speaking of the mound upon which stood the council house in their town of Cowe,† and it is of course very probable that the Indians of whom he made the inquiry did not know who built this particular mound; at least there can be no doubt that they told him so, and that he believed them.

Now Bartram's visit to the Cherokees was a hurried one; he saw but few of their towns, and could not possibly have conversed with but a small portion of their people, and yet his statement is couched in the

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* Bartram's *Travels*, p. 367: Philadelphia, 1791. He adds: "But they have a tradition common with the other nations of Indians, that they found them in much the same condition as they now appear, when their forefathers arrived from the West and possessed themselves of the country after vanquishing the nations of red men who then inhabited it, who themselves found these mounds when they took possession of the country, the former possessors delivering the same story concerning them."

† This distinction must be kept in mind, as *l. c.*, p. 348, he speaks of "vast heaps of stones" that were "Indian graves, undoubtedly."

broadest terms possible, and includes all the members of the tribe of every age, size, sex, and condition. Obviously his assertion is not warranted by the facts, nor is it borne out by the testimony of concurrent writers. So far from being without any tradition on this subject, this people can be shown to have had several, or at all events they so reported. Thus, about the year 1782, Oconostoto, who had been for sixty years one of their chiefs, being asked by Governor Sevier,* of Tennessee, who built the earth-works in their country, and particularly "the remarkable fortification," as it is called, on the Hiawassee River, answered that "it was handed down by their forefathers, that these works were made by the *white people* who had formerly inhabited the country." Gen. Geo. Rogers Clark,† who probably knew as much of Indian character as any one who has ever written on the subject, says positively that there was a tradition among the Cherokees to the effect that the works in their country were built by their ancestors; and this statement is borne out by the chroniclers of De Soto's expedition,‡ as well as by the testimony of Adair,§ who seems to have had no doubt by whom these mounds were built, or for what purpose, though he admits that some of them were beyond the reach of tradition.

Here then in this one tribe, we have several accounts of these works. They can not all be true, and it is possible that neither one of them may be; and yet either one of them is a sufficient answer to

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* See letter of Gov. Sevier in Stoddard's *Sketches of Louisiana*, p. 483: Philadelphia, 1812. Being questioned as to who these white people were, the old chief replied: "That he had heard his grandfather and other old people say that they were a people called the Welsh," etc. For a summary of what has been written about a Welsh Nation in America, consult chapter xvii of the above work, and also Priest's *American Antiquities*, pp. 229 *et seq.*: Albany, 1838; and Burder's *Welch Colony*, a pamphlet published in London in 1797.

† "I think the world is to blame to express such great anxiety to know who it was that built these numerous and formidable works, and what hath become of that people. They will find them in the Kaskaskias, Peorias, Kahokias (now extinct), Piankeshaws, Chickasaws, Cherokees, and such old nations, who say they grew out of the ground where they now live, and that they were formerly as numerous as the trees in the woods; but affronting the Great Spirit, he made war among the nations, and they destroyed each other. This is their tradition, and I can see no good reason why it should not be received as good history—at least as good as a great part of ours:" MSS. of Gen. Geo. R. Clark, in vol. iv, Schoolcraft, *Indian Tribes of the United States*, p. 135.

‡ In the *Tenth Annual Report of the Peabody Museum* at Cambridge, pp. 75 *et seq.*, I have given some of the reasons for believing that the Cherokees built mounds and earth-works.

§ "We frequently meet with great mounds of earth, either of a circular or oblong form, having a strong breastwork at a distance around them, made of the clay which had been dug up in forming the ditch on the inner side of the inclosed ground, and these were their forts of security against an enemy. Three or four of them are, in some places, raised so near to each other as evidently for the garrison to take any enemy that passed between them. They were mostly built in low lands; and some are overspread with large trees, beyond the reach of Indian tradition:" *History of the American Indians*, p. 377: London, 1775.

the statement that the Indians had no tradition as to the origin of these structures, or the purpose for which they were built. Nor must it be supposed that the Cherokees were alone in this respect; neither were these stories confined to any one stock or family of tribes. They are found on both sides of the Ohio, and were as current (and for that matter as varied and often quite as contradictory) among nations of the Huron and Algonquin families as they were among the Cherokees. In fact, it is believed to be the exception to find a single prominent tribe living within the region of the mounds in which some tradition on the subject of their origin was not more or less common. Whether these traditions were true or false, or whether the event that was purported to be handed down was fact or fable, are points which it is not necessary to discuss. All that I am called upon to show is, that the Indians had traditions, no matter what their character, upon this subject; and in doing this, I shall limit myself to a representative tribe from each family, and by way of making the tradition as definite as possible, will pick out typical works or groups, situated in different portions of the country, so that there can be no doubt as to the particular tribe, or the precise kind of earthwork that is meant.

First of all, let us take up the mounds and inclosures of western New York, and see what the Iroquois had to say as to their origin. According to one account, the country "about the lakes was thickly inhabited by a race of civil, enterprising, and industrious people, who were totally destroyed, and whose improvements were taken possession of by the Senecas."* The Rev. Mr. Kirkland, while on a missionary tour to this tribe, A. D. 1788, visited several of these "old forts," one of which, situated in Genesee County, near Batavia (Squier), and known to the Indians as the "double-fortified town, or a town with a fort at each end," is thus described: The first of these forts "contained about 4 acres of ground. The other, distant from this about 2 miles, and situated at the other extremity of the ancient town, inclosed twice that quantity of ground. The ditch around the former was about 5 or 6 feet deep. A small stream of water and a high bank circumscribed nearly one-third of the inclosed ground. There were the traces of six gates or avenues round the ditch, and near the center a way was dug to the water. - - - A considerable number of large thrifty oaks had grown up within the inclosed ground, both in and upon the ditch; some of them appear to be at least two hundred years old or more. - - - Near the northern fortification, which was situated on high ground, he found the remains of a funeral pile. - - - The earth was raised about 6 feet above the common surface, and betwixt 20 and 30 feet diameter. The bones appeared on the whole surface of the raised earth, and stuck out in many places on the sides."† According to the same author, Indian

* Yates and Moulton, *History of New York*, vol. I. p. 40; New York, 1824.

† MSS. of Rev. Mr. Kirkland, in Moulton's *New York*, vol. I, p. 16.

tradition says "these works were raised, and this battle was fought betwixt the Senecas and Western Indians. - - - In this great battle the Senecas affirmed that their ancestors won the victory. Some say their ancestors had told them there were 800 of their enemies slain; others include the killed on both sides in that number. Be this as it may, all their historians agree that the battle was fought where this heap of slain are buried, before the arrival of the Europeans, some say three, some four, others five lives or ages, reckoning a life or age one hundred winters or colds."* Another tradition represents that these works were erected by the ancestors of the Iroquois in their wars with other tribes † and with the French.‡ Assuming that these two traditions refer to different periods in the national life of the Six Nations, they do not conflict. In fact, they fit in together very closely, and as Mr. Squier has shown that these remains are but the abandoned village sites of the recent Indians,§ they may be said to be sustained by the traditions of the Iroquois as to their expulsion from the region near Montreal, and their seizure and occupation of central and western New York.‖

Proceeding towards the southwest, we come next to the Ohio system

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* MSS. of Rev. Mr. Kirkland, *l. c.*, p. 39. It will be seen that this account leaves it uncertain whether these works were erected by the Senecas or the Western Indians. So far as my purpose is concerned, it is immaterial which of these tribes built them. The following extract from Governor DeWitt Clinton will, however, clear up the difficulty: "Some of the Senecas told Mr. Kirkland, the missionary, that those in their territory were raised by their ancestors in their wars with the Western Indians." *Coll. N. Y. Hist. Soc.*, vol. II, p. 92. Compare Cusick's *History of the Iroquois*, part II, published in Schoolcraft's *Indian Tribes*, vol. V, pp. 632 *et seq.*

† *Notes on the Iroquois*, p. 442.

‡ Farmers Brother told Dr. King that the mounds were thrown up against the incursions of the French. This was about 1810, at which time he was 94 years old: Drake's Indians of North America, fifteenth edition, p. 604. There is another tradition given by Governor De Witt Clinton in the *Collections of the N. Y. Hist.. Soc.*, vol. II, p. 92, to the effect that "these works were thrown up by an army of Spaniards," etc. I do not think it necessary to give it in the text, as it is probable that the tradition is as false as the event to which it relates is improbable. However, it may be well to add that Brant, the famous Mohawk chief, in vol. II, p. 484, of his life, speaks of a tradition that "prevailed among the different nations of Indians throughout that whole extensive range of country, and had been handed down time immemorial, that in an age long gone by there came white men from a foreign country, and, by consent of the Indians, established trading houses and settlements where these tumuli are found. A friendly intercourse was continued for several years; many of the white men brought their wives and had children born to them - - - These circumstances at length gave rise to jealousies," and the colony was ultimately destroyed. Brant expressed no opinion as to the truth of the tale, but added: "that from the vessels and tools which had been dug up in those mounds, or found in their vicinity, it was evident that the people who had used them were French.

§ Aboriginal Monuments of New York, in *Smithsonian Contributions to Knowledge*, vol. II, chap. VI.

‖ Morgan. *League of the Iroquois*, p. 5. Bartram (John) *Observations*, etc., p. 23; London, 1751. Colden, *Five Nations*, p. 23. De Witt Clinton, *l. c.*, p. 92. *Relation en l' année* 1660, p. 6.

of works, and here again we have several traditions as to their origin. One of these, handed down among the Lenni Lenape—an Algonquin tribe—is to the effect that when they had reached the Mississippi in their migration eastward, they found the country east of that river inhabited by a powerful nation, called the Allegewi, who had many large towns built on the great rivers flowing through their land. At first they gave the Lenni Lenape, or Delawares, as we call them, leave to pass through their country, and seek a settlement farther to the east; but for some reason they attacked them whilst crossing the river, and inflicted great loss upon them. The Lenni Lenape then formed an alliance with the Mengwe or Iroquois, who were also on their way to the east in search of a home, and together they made war upon the Allegewi, stormed their towns and fortifications, and finally expelled them from the country. Heckewelder,* to whom we are indebted for the story, says that he had seen many of their fortifications, one of which, situated on the Huron River, east of the Sandusky, about 6 or 8 miles from Lake Erie, he describes as consisting of "walls or banks of earth regularly thrown up, with a deep ditch on the outside. - - - Outside of the gateway were a number of large flat mounds, in which, the Indian pilot said, were buried hundreds of the slain Allegewi." In another account † we are told that it was a tradition of the Kaskaskias, Piankeshaws, and other tribes, that these "fortified towns," "entrenched encampments," or "garrisoned forts, many of them with towers of earth of considerable height to defend the walls with arrows and other missile weapons, - - - were the works of their forefathers," who were as numerous as the trees in the wood; but that, having affronted the Great Spirit, he made them kill one another.

Speaking of the collection of mounds in the river bottom opposite St. Louis, just below the old French village of Cahokia, one of the largest mound centers in the United States, Baptist Ducoign, a Kaskaskia chief, told Gen. Geo. Rogers Clark that it was "the palaace of his forefathers, when they covered the whole (country) and had large towns; that all those works we saw there were the fortifications round the town, which must have been very considerable; that the smaller works we (saw) so far within the larger, comprehended the real palaace; that the little mountain we there saw flung up with a basin on top, was a

* *Historical account of the Indian Nations*, pp. 29 *et seq.*: Philadelphia, 1819. See also that curious mixture of fact and fable, Cusick's *History of the Six Nations*. John Norton, a Mohawk chief (in vol. II of Life of Joseph Brant, note on p. 486: Albany, 1865), says, "There was a tradition in his tribe that they were constructed by a people who, in ancient times, occupied a great extent of country, but who had been extirpated; that there had been long and bloody wars between this people and the Five Nations, in which the latter had been finally victorious."

† MSS. of Gen. George Rogers Clark in vol. IV of Schoolcraft, *Indian Tribes*, pp. 134 and 135. See also *Notes on the Iroquois*, p. 162, and Brackenridge, *Views of Louisiana*, p. 185: Pittsburg, 1814.

tower that contained part of the guard belonging to the prince, as from the top of that height they could defend the King's house with their arrows," etc.*

If now we cross the Ohio, and inquire of the Creeks or Muscogees as to the origin of the works that are scattered throughout their country, we shall find that they too ascribed them to their ancestors, though they differed as to the purposes for which some of them were erected. According to one account a certain class of "conic mounds of earth" were thrown up as places of refuge against high water; whilst a more probable tradition speaks of them as tombs of the dead, or parts of "an ancient Indian town,"† possibly the sites of the cabins of their chiefs and of their council-houses or temples. In 1847, Sekopechi,‡ one of the oldest Creeks then living, speaking of the former condition of his tribe, said that they erected breast-works of a circular shape for the protection of their families, and that the mounds had no existence previous to their arrival. Adair§ tells us that "they had a special name for their old round earthern forts;" and Bartram,‖ speaking of "the artificial mounds or terraces, squares and banks encircling considerable areas"—the monuments or traces of an ancient town that once stood on the east bank of the Oemulgee, near the old trading road, adds: "If we are to give credit to the accounts the Creeks give of themselves, this place is remarkable for being the first town or settlement

*MSS. of Gen. Clark, *l. c.*, p. 135. He adds: "I had somewhere seen some ancient account of the town of Kaskaskia, formerly containing 10,000 persons. There is not one of that nation at present known by that name. - - - I one day set out to see whether we could discover signs of such a population. We easily and evidently traced the town for upwards of 5 miles in the beautiful plain below the present town of Kahokia. There could be no deception here, because the remains of ancient works were thick—the whole were mounds, etc. - - - Fronting nearly the center of this town, on the heights, is a pinnacle called the Sugar (Loaf), from its figure. - - - I at once saw that it was a hill, shaped by a small brook breaking through the (larger) hill till it had formed a very narrow ridge. This had been cut across, and the point shaped in the form of a sugar loaf, perhaps to place an idol or a temple on, as it could not be more conspicuous. It is of a very considerable height, and you are obliged to wind round it to ascend on horseback."

†Hawkins, *Sketch of Creek Country*, p. 38. Schoolcraft (vol. IV, p. 127), quoting a MSS. copy of the "Sketch," says: "They were also designed to entomb the remains of their distinguished dead." Bartram (*Travels*, p. 522) says that the Indians have a tradition that the vast four-square terraces, chunk yards, etc., at Apalachucla, old town, were "the ruins of an ancient Indian town and fortress."

‡Schoolcraft, *Indian Tribes*, I, p. 267.

§ *History of North American Indians*, p. 67.

‖"On the east banks of the Oemulgee this trading road runs nearly 2 miles through ancient Indian fields, which are called the Oemulgee fields; they are the rich low lands of the river. On the heights of these low grounds are yet visible monuments or traces of an ancient town, such as artificial mounts or terraces, squares, and banks, encircling considerable areas. Their old fields and planting land extend up and down the river, 15 or 20 miles from this site." *Travels through Florida*, p. 54: Philadelphia, 1791.

where they sat down (as they term it) or established themselves after their emigration from the West, beyond the Mississippi, their original native country. On this long journey they suffered great and innumerable difficulties, encountering and vanquishing numerous and valiant tribes of Indians, who opposed and retarded their march. Having crossed the river, still pushing eastward, they were obliged to make a stand and fortify themselves in this place as their only remaining hope, being to the last degree persecuted and weakened by their surrounding foes. Having formed for themselves this retreat, and driven off the inhabitants by degrees, they recovered their spirits, and again faced their enemies, when they came off victorious in a memorable and decisive battle. They afterwards gradually subdued their surrounding enemies, strengthening themselves by taking into confederacy the vanquished tribes."* These are a few of the traditions that have come down to us as to the origin of these works, and although, when considered by themselves, they are not perhaps of much historical importance, yet, inasmuch as the question is not as to their truth, but as to their existence, they answer my purpose as well as if each one of them were founded on fact, and had been handed down from generation to generation without a break or a blemish.

In regard to the credibility of these different accounts, a few words may not be out of place. As has been said before, they can not all be true, though there is no reason why some of them may not rest upon a basis of fact. Take for instance the tradition, found in some shape among almost all tribes, that these works were built by their ancestors, and test it as we may, it will be seen that so far from being impossible, it is rendered more than probable by the fact that some of the most elaborate of these remains can be shown to have been erected since the arrival of the whites. The evidence of this is furnished by the mounds themselves, or rather by their contents, and consists of articles of European manufacture that were buried with the body over which the mound was originally erected. As an instance of this, take the series of works at Circleville, Ohio, to which a reference has been made on a preceding page.† It is composed of a circle, square, and mounds, all of which are

*And yet, on p. 520, he tells us that the region between the Savanna and Ocmulgee rivers "was last possessed by the Cherokees, since the arrival of the Europeans, but they were afterwards dispossessed by the Muscogulges; and all that country was, probably, many ages preceding the Cherokee invasion, inhabited by one nation or confederacy, who were ruled by the same system of laws, customs, and language; but so ancient that the Cherokees, Creeks, or the nation they conquered, could render no account for what purpose these monuments were raised." On p. 456 the same statement is made in regard to a post or column of pine, 40 feet high, that stood in the town of Autassee, "on a low, circular, artificial hill," and as this pole could not have been standing for very many generations, it is evident that the Indian's account of what his ancestors did or did not know must be taken with a great deal of allowance.

† See *ante*, foot-note † on page 557.

so joined together that they must have formed parts of one connected whole. Near the center of the circle or, as it is called, "the round fort," which as we have seen, had once been inclosed by palisades, was a tumulus of earth about 10 feet in height and several rods in diameter at its base. On its eastern side and extending 6 rods from it, was a semicircular pavement composed of pebbles, such as are now formed in the bed of the Scioto River, from whence they appear to have been brought. The summit of this tumulus was level, nearly 30 feet in diameter, and there was a raised way to it leading from the east, like a modern turnpike.* The earth composing this mound was entirely removed in the presence of Mr. Atwater, and there were found lying on the original surface of the ground, and about 20 feet apart, the remains of two human skeletons that had evidently been burned. With one of these skeletons there was "the handle either of a small sword or a large knife, made of an elk's horn; around the end where the blade had been inserted was a ferrule of silver which, though black, was not much injured by time. Though the handle showed the hole where the blade had been inserted yet no iron was found, but an oxide remained of similar shape and size." With the other skeleton "there was a large mirrour about 3 feet in length, 1½ feet in breadth, and 1½ inches in thickness. This mirrour was of isinglass (*mica membranacea*), and on it (was) a plate of iron, which had become an oxide; but before it was disturbed by the spade resembled a plate of cast iron."

A quantity of arrow-heads and spear-points were found with one of the skeletons; but of these it is unnecessary to speak, as they probably did not differ from those that lie scattered about everywhere in the Ohio Valley, and they can not therefore (except indirectly) throw any light upon the origin of these works. Not so however with the articles of iron and silver. These do tell a story; and whilst they do not indicate the precise period of time when this mound was erected, yet they enable us to say, with some degree of certainty, that it must have been subsequent to the arrival of the whites, for the reason that the nations that held the Mississippi Valley previous to that event, whether Mound-builder or recent Indian, may in a general way be said to have been unacquainted with any metal except native copper; and this they simply hammered into shape, or possibly "having melted it," they "spread it into sheets," as Champlain (*Voyages*, vol. II, p. 236: Boston, 1878) tells us they sometimes did, before submitting it to the process of malleation. Of the manufacture of iron they appear to have been ignorant; and though the recent Indians were unquestionably acquainted with silver, beat it into ornaments, and in all probability

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* *Archæologia Americana* vol, I, pp. 177, *et seq.* See also Squier, *Abor. Mon. of New York*, p. 107; Stone, *Life of Brant*, vol. II, p. 485, and Schoolcraft, *Lead Mines of Missouri*, p. 274, for notices of other mounds that have been built in the State of Ohio within comparatively recent times.

sometimes overlaid copper with it,* yet the evidence of its use is relatively so slight as scarcely to merit recognition. Upon these points all archæologists are agreed; and when therefore we are told, upon authority that has never been questioned, that implements of iron and silver were found with the charred bones of a person, over whose remains a most elaborate mound had been erected, it is proof positive of the recent origin of this particular mound, and inferentially of the group of works of which it formed a component part. There is no escaping this conclusion except upon the theory that the people who erected these works, supposing them to have belonged to a different race from the Indians, were acquainted with the use of iron and silver; and to admit this is virtually to re-write the archæology of the Mississippi Valley.

Nor is this the only instance in which objects of European manufacture have been found under such circumstances as to indicate that they were used by the people who found shelter behind these earthen walls. In Tennessee, near Murfreesboro,† similar discoveries have been made,

* "One of them had hanging about his neck a round plate of red copper, well polished, with a small one of silver hung in the middle of it; and on his ears a small plate of copper, with which they wipe the sweat away from their bodies:" Ribault (1562), in *Hist. Coll. of Louisiana*, p. 178: New York, 1875. Both Ribault and Laudonnière make repeated mention of silver and even gold, but the latter writer (Hakluyt, vol. III, p. 369) tells us that it is "gotten out of the shippes that are lost upon the coast, as I have understood, by the sauages themselues." Hariot (Hakluyt, vol. III, p. 327: London, 1810), speaks of "two small pieces of silner grosly beaten - - - hanging in the ears of a Wiroans; - - - of whom, through inquiry, - - - I learned that it had come to his hands from the same place or neere, where I after understood the copper was made, and the white graines of metall found. The aforesayd copper we also found by tryall to holde silner." In this connection the copper "bosses overlaid with a thick plate of silver," found by Dr. Hildreth in a mound at Marietta, Ohio, becomes of interest. Judge Force, to whom I have so often had occasion to refer, examined one of these specimens, and tells us (*To what Race did the Mound-builders Belong*, p. 49), that "it is native copper hammered into shape." He also adds that "in the Lake Superior mines silver is found in connection with the copper, and the miners there now, taking advantage of good specimens, hammer them into rings, with the silver on the exterior surface, making copper rings, silver-plated by nature, precisely as the Mound-builder artisan did who made the boss at Marietta," and we may add, as the Florida Indian did, who made the ornament spoken of by Ribault. In another mound at Marietta, half a mile east of the earthworks, was found a silver cup, evidently not of Indian workmanship, which Schoolcraft (*Lead Mines of Missouri*, p. 274: New York, 1819) describes. It belonged to a Mr. Hill, of Cahokia, and, according to that gentleman, had been brought to light by the gradual washing away of the mound by a small stream which ran at its base.

† Dans l'angle nord-ouest du comté de Franklin, au confluent de deux branches les plus méridionales du Duck, on voit les ruines d'un vieux fort indien, nommé *Stone-Fort*, qui couvre une étendue de trente-deux acres. - - - A la distance d'un demi-mille environ au nort et au nord-ouest, l'on rencontre deux tertres, dont l'un a cent pieds de longueur et vingt-cinq de hauteur sur vingt de largeur, et l'autre soixante pieds de longueur et vingt de hauteur sur dix-huit de largeur. On voit croitre sur les murs, comme sur les tertres, des arbres aussi grands que ceux des forêts voisines. On a découvert récemment dans un de ces tertres un sabre de deux pieds de long, qui

whilst in New York * and Florida these "finds," as they are commonly called, have been so frequent as to make it unnecessary to refer to them in detail, and I content myself with the following extract from the fourteenth annual report of the Peabody Museum, † which it is needless to say is heartily indorsed. Speaking of some discoveries made by Dr. David Mack, jr., in the course of his explorations in Orange County, Fla., Mr. Putnam holds the following emphatic language: "One group of mounds was inclosed by an embankment, and was very likely the site of an Indian village. In a burial mound in this group a number of ornaments made of silver, copper, and brass were found, also glass beads and iron implements, which were associated with pottery and stone implements of native make. This furnishes conclusive evidence that the Indians of Florida continued to build mounds over their dead after European contact; for the care with which the exploration was made, and the depth at which the skeletons and their associated objects were found are conclusive as to the burials being the original ones and not those of an intrusive people." It is unnecessary however to pursue this branch of the subject any farther. The instances quoted above, admitting them to be true (and I do not see how it can be doubted), prove very clearly the recent origin of the particular mounds and works to which they refer. To increase the number of such extracts is simply to accumulate evidence upon a point about which there can not be two opinions.

Having thus cleared our minds of some of the illusions in which this subject has been enveloped, let us now turn to the early chroniclers, and see what they really do tell us of the origin of these works. In examining into this evidence, the division heretofore made of these remains, into mounds and embankments or inclosures, will be adhered to, though the order in which they are to be taken up will be reversed, and the mounds will be first considered. These will be treated under the heads of (1) Stone heaps or cairns; (2) Conical mounds of earth or burial mounds, and (3) Truncated or temple mounds. There are, of course, other divisions, but for my purpose these are believed to be sufficient, as, with the exception of the animal mounds, about which nothing definite is known,‡ all the rest, so far as size and mode of con-

diffère par la forme de toutes les armes de cette espèce dont on se soit servi depuis l'arrivée des Européens. Des débris de vaisselle et plusieurs briques entières de neuf pouces carrés et de trois pouces d'épaisseur ont été trouvés au même lieu:" Warden, *Antiquités de l'Amérique Septentrionale*, p. 51: Paris, 1827.

* For an account of these works see Schoolcraft, *Notes on the Iroquois*, Clark's *Onondaga*, and Squier, Aboriginal Monuments of New York, in vol. II, *Smithsonian Contributions to Knowledge*.

† Page 17, Cambridge, 1881. See also *Report Smithsonian Institution* for 1877, pp. 298 and 305; Jones, *Antiquities of the Southern Indians*, p. 131, and *Twelfth Annual Report of the Peabody Museum*, in vol. II, p. 468.

‡ Unless the explanation given in that curious book, "The Traditions of Decoodah," should be accepted as authority, and this is scarcely advisable in the present state

struction are concerned, may be brought under one or the other of these heads, though it is not intended thereby to assert anything as to the object or purpose for which they were erected, except in so far as it is made known to us by the authorities to whom a reference may be necessary.

First. Beginning with the stone heaps or cairns, we are informed that they were either intended to commemorate some notable event, as a treaty of peace,* a victory, the settlement of a village, the passage of a war party,† or else they were thrown up as landmarks, or as memorials over the dead.‡ They seem to have been very widely distributed throughout the area of the United States, as they are to be found as far to the eastward as New England; § they are more or less

of our knowledge. The only statement that I find in any of the early chroniclers which can possibly be construed into a reference to these mounds is in Charlevoix (*Travels*, vol. II, p. 48), and even in this case it can only be so construed by *supposing* that by "the great beaver" is meant the "beaver" gens of some tribe. Charlevoix there speaks of a mountain, near Lake Nipissing, in the shape of a beaver, and says: "The Indians maintain that it was the great beaver who gave this form to the mountain after he had made choice of it for his burial place. They never pass - - - without offering him the smoke of their tobacco."

* Beverly, *Virginia*, book III, p. 27: "They use formal embassies for treating, and very ceremonious ways in concluding of peace, or else some other memorable action, such as burying a tomahawk and raising an heap of stones thereon." Brinton, in Amer. Antiquarian for October, 1881, quoting Blomes, says of the tribes south of the Savannah river, "that they erected piles or pyramids of stones on the occasion of a successful conflict, or when they founded a new village."

† "We observed a pile of stones, - - - which I was informed had been thrown up as a monument by the Osages when they were going to war, each warrior casting a stone upon the pile:" Nuttall, *Arkansa Territory*, p. 149: Philadelphia, 1821. This may have been merely a "landmark:" *Our Wild Indians*, by Col. Dodge, p. 557: Hartford, 1882.

‡ "To perpetuate the memory of any remarkable warriors killed in the woods, I must here observe, that every Indian traveller as he passes that way throws a stone on the place, according as he likes or dislikes the occasion or manner of the death of the deceased:" Adair, p. 184.

§ Mountain Monument, in Berkshire County, Mass., is so called from the fact that at its southern extremity is, or was a few years since, a pile of small stones, erected, according to tradition, in memory of a woman of the Stockbridge tribe, who killed herself by leaping from the precipice:" W. C. Bryant, *Notes to Poems*: Philadelphia, 1849. According to the *Amer. Journal of Science*, vol. VII, p. 159, mention is made in Dr. Dwight's *Travels in Connecticut*, etc., "of two of these stone tumuli, which appear to have been erected over offenders against the law." See also Aboriginal Mon. of New York, p. 160, for an account taken from Hopkins's Memoir of the Housatonic Indians, of the erection of "a large heap of stones, - - - probably 10 cart loads, in the way to *Wawhtukook*, which the Indians have thrown together as they passed by the place; for it used to be their custom, every time one passed by, to throw a stone upon it," etc. I must confess that I don't know where this cairn was situated or when it was built, and it does not much matter, as from the name of the tribe it is evident they were of New England origin. See also Dorman, *Origin of Primitive Superstitions*, p. 185: Philadelphia, 1881, and Haven, in vol. VIII of *Smithsonian Contributions to Knowledge*, pp. 31, *et seq.*

numerous in New York,* throughout the Ohio Valley,† and the States still further to the south,‡ whilst in the West they are known to have been erected, within the present generation, by "tribes living in the Rocky Mountains and the Sierra Nevadas."§ In point of size there is a wide difference among them. A large majority consists of not more than "two or three cart-loads of stone," though Squier speaks of one situated near the Indian trail that led from the Shawnee village at Chillicothe to the mouth of the Scioto River as being rectangular in shape, and originally quite symmetrical in outline, and measuring 106 feet long by 60 broad, and from 3 to 4 feet high.‖ Where intended as memorials of the dead they are sometimes piled up over a single corpse, or they may serve to mark the site of one or more of those general interments, when the dead of an entire village or a clan, for a number of years, were collected together and buried in one common grave.¶ This latter form of burial was not confined to any one family or stock of tribes, but seems to have been common to all, and was always attended with great ceremony.

The Jesuit Fathers Breboeuf** and Lallemant†† give us very full and

* A pile of stones. - - - Indian tradition says that a Mohawk murdered a brother (or two of them) on the spot, and that this tumulus was erected to commemorate the event. - - - They all cast a stone upon the pile:" Howe, *Historical Collections of New York*, p. 278: New York, 1842.

† *Archæologia Americana*, vol. I, pp. 131–184. *Anc. Mon. of the Mississippi Valley*, p. 184. See also a note to p. 362, vol. II, *Reports of the Peabody Museum:* Cambridge, 1880.

‡ "Seven heaps of stones being monuments of seven Indians slain by the Sinnegars:" Lawson, Carolina, p. 44. See also Jefferson, *Notes on Virginia*, p. 191. and Jones, *Antiquities of the Southern Indians*, p. 127, for an account of such cairns in Virginia and Georgia.

§ Yarrow, *Mortuary Customs of the North American Indians*, p. 48: Washington, 1880. See also *United States Geographical Surveys*, west of the 100th meridian, vol. VII, pp. 392 and 394. One of these cairns was 25 feet long, 20 broad, and 10 feet high, and covered the body of a warrior called by the Mormons Nabbynunck. See also *Reconnoissance of Northwestern Wyoming*, by Capt. Jones, U. S. Army, p. 276, where we are told that among the Shoshones "the dead are usually buried in shallow graves and covered with a low mound of loose stones."

‖ *Anc. Mon. Miss. Valley*, p. 184.

¶ Col. C. W. Jenckes, superintendent of the Corundum mines in western North Carolina, says: "We have Indians all about us with traditions extending back for five hundred years. In this time they have buried their dead under huge piles of stones. We have at one point the remains of 600 warriors under one pile:" Foster, *Prehistoric Races*, p. 149: Chicago, 1873. As the Cherokees had held the region where this cairn was situated from time immemorial, this was probably one of their graves. That they did bury their dead in this fashion may be inferred from a statement of Adair, who tells us, in a note to p. 185, that "the Cheerake do not now collect the bones of their dead, yet they continue to raise and multiply heaps of stones as monuments of their dead." See also *Anc. Mon. of the Miss. Valley*, p. 184, for an account of a similar interment in Pickaway County, Ohio.

** *Relation en l'année* 1636, chap. viii and ix: Quebec, 1858.

†† *Relation*, A. D. 1642, pp. 94 *et seq.*

interesting accounts of the manner in which these funerals were conducted among the Huron and Algonquin tribes of the north; and the frequent mention made of the custom of the Indians south of the Ohio of preserving the bones of the dead* leaves no doubt as to the prevalence of this form of interment throughout all that region, from the time of De Soto† down to a comparatively recent period, even if there were not other and positive evidence of the fact. It is worthy of note, however, that neither one of the Jesuit fathers named makes any mention of the erection of a mound or cairn upon the occasion of one of these general burials, or, in fact, at any other time, though Morgan, speaking of the funeral customs of the Iroquois, is of the opinion that the "barrows and bone mounds, which have been found in such numbers in various parts of the country," are to be ascribed to the practice of disposing of their dead in this fashion, and this is confirmed by De Vries.‡ Be this as it may, there seems to be good ground for the assertion that some of the tribes belonging to the Huron-Iroquois family were, at one time and under certain conditions, in the habit of erecting stone heaps over the single graves in which their dead were temporarily deposited. Lafitau § states the fact positively, and Adair ‖ tells us, on the authority of "a gentleman of distinguished character," that the Mohawks—one of the Six Nations—were accustomed thus to honor their dead. From other sources we learn that the Onondagas, another member of the same confederacy, whenever they lost a friend away from

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* Bartram, *Travels*, p. 514. Adair, p. 183. Lawson, p. 182. Du Pratz, vol. II, p. 214, Beverly, book III, p. 29. Bossu, *Travels through Louisiana*, vol. I, p. 298: London, 1771. Bernard, Romans, pp. 89, 90.

† Knight of Elvas, in *Hist. Coll. of Louisiana*, part II, p. 125. La Vega, *Hestorie de la Floride*, première partie, pp. 264 *et seq.*, and seconde partie, pp. 39 *et seq.*: Paris 1709.

‡ *League of the Iroquois*, p. 173. "I have seen at the north (Fort Orange), great multitudes of Indians assembled, who had collected together the bones of their ancestors, cleaned them, and bound them up in small bundles. They dig a square grave, the size and length of a person. - - - They then bury the bones in the grave, with a parcel of Zeewan, and with arrows, kettles, knives, paper, and other knick-knacks, which are held in great esteem by them, and cover them with earth, and place palisades around them as before mentioned." The "as before mentioned" refers to a grave that was "seven or eight feet in the shape of a sugar-loaf." De Vries, *Voyages*, p. 164: New York, 1853.

§ "Leurs fosses sont de petites loges creusées en rond comme des puits; - - - on les natte en dedans de tous cotés avec des écorces; et après y avoir logé le cadavre, on y fait une voute presque au niveau du sol avec des écorces semblables, et des pieux qu' on charge de terre et de pierres à une certaine hauteur, qui fit aussi donner à ces tombeaux les noms d' *Agger* et de *Tumulus*:" *Moeurs des Sauvages Ameriquains*, vol. II, p. 416.

‖ "Many of these heaps are to be seen in all parts of the continent of North America. - - - Although the Mohawk Indians may be reasonably expected to have lost their primitive customs, by reason of their great intercourse with foreigners, yet I was told by a gentleman of distinguished character that they observe the aforesaid sepulchral custom to this day:" *North American Indians*, note to p. 185.

home, buried him with great solemnity, and ever after when they passed that way, visited the spot, usually singing a mournful song, and casting stones upon it." *

Among the tribes of the Algonquin family, as well as among those inhabiting the Gulf States, and which, for the sake of convenience, we have called the Appalachians, the custom of erecting these stone heaps or cairns seems to have been more or less prevalent. Vander Donck tells us that the Indians of New Netherlands buried in graves, above which "they placed a large pile of wood, stone, or earth," and around this "they placed palisades resembling a small dwelling." † In Virginia, according to Capt. Smith, the Powhatanic tribes had certain altar stones which stand "apart from their temples, some by their houses; and others in the woods and wildernesses; where they have had any extraordinary accident or encounter. As you travel by them they will tell you the cause of the erection, wherein they instruct their children; so that they are instead of records and memorials of their antiquities." ‡ In Lawson's account of his journey through the Carolinas he speaks of a "sort of tomb; as where an Indian is slain, in that very place they make a heap of stones (or sticks, where stones are not to be found); to this memorial every Indian that passes by adds a stone to augment the heap, in respect to the deceased hero." § The Cherokees, as we have seen above, also buried their dead in this same manner; ‖ and among the Chickasaws, Choctaws, and tribes belonging to the Creek confederacy, with whom Adair lived and traded for so many years, it was not unusual, in the woods, "to see innumerable heaps of small stones in those places where, according to tradition, some of their distinguished people were either killed or buried till their bones could be gathered; there they add *Pelion* to *Ossa*, still increasing each heap, as a lasting monument and honor to them and an incentive to great actions." ¶

Among some of the tribes living to the west of the Mississippi, especially those inhabiting portions of the region now known as the

* J. V. H. Clark, *Onondaga*, vol. I, p. 52: Syracuse, 1849. Mr. Clark seems to have derived his information as to the former customs of the Onondagas from the account furnished by La Fort (so he wrote his own name), principal chief of the Onondagas, and "keeper of the council fire of the Six Nations." who died October 5, 1848. Macauley, *New York*, vol. II, p. 239, says: "Sometimes they raised heaps of stones over the bodies of distinguished chiefs," but he does not give his authority for the statement.

† New York *Hist. Coll.*, new series, vol. I, p. 202. These Indians were Lenni Lenape, or, as we call them, Delawares, and their congeners. Except that sand was used instead of stones or earth, the Indians of Plymouth, Mass., probably buried in much the same manner. See Purchas *Pilgrims*, vol. IV, p. 1847, where the same comparison—"of the grave to an Indian house"—is used.

‡ Purchas *Pilgrims*, vol. IV, p. 1702.

§ *History of Carolina*, p. 22: London, 1718.

‖ Bartram, *Travels*, p. 348. Adair, note to p. 185.

¶ *Hist. of North American Indians*, p. 184.

States of Missouri, Kansas, and Arkansas, this same custom is said to have obtained. The Osages, as is elsewhere stated, erected, on one occasion, a pile of stones, as a monument, when they were going to war; and if we may credit the account given by Hunter of the manners and customs of this and some other Western tribes,* they sometimes, "at or soon after burial, cover the grave with stones, and for years after occasionally resort to it, and mourn over or recount the merits and virtues of its silent tenant."† This was not however the only form of interment practiced among them, as we are told that "this ceremony was performed differently, not only by different tribes, but by the individuals of the same tribe, - - - the body being sometimes placed on the surface of the ground, between flat stones set edge upwards, and then covered over, first by similar stones, and then with

* "What remains to be said of the Indians relates more particularly to the Osages, although it will apply with almost as much propriety to the Kansas, Mahas, and Ottawas. In fact, if we except the roving bands, the circumstances of the Indians settled immediately to the west of the Missouri and Mississippi, are so very similar that the delineation of any particular nation or tribe will answer for them all," etc.: Hunter's *Captivity*, p. 213: London, 1823. Exactly what amount of credence is to be placed in these "Memoirs" is a point about which opinions differ. Gen. Cass, in the *North American Review* for January, 1826, makes a savage attack upon the book, and introduces letters from John Dunn (whose name Hunter took, and who had "treated him like a brother or son"), Gen. Wm. Clark, and others, to the effect that they never knew any such person, and that it was not possible for the events of which he speaks to have happened without their knowledge. This is to some extent negative evidence, and does not amount to much; but even if it were true, and Hunter was a myth, and the work that bears his name was a compilation, it would only invalidate so much of the narrative as refers to his personal experiences whilst a prisoner. All the rest, including that portion devoted to a description of the "Manners and Customs of some of the Western Indians," would then become simply a question of fact, and as such would have to be decided, as all such matters are, by a comparison of authorities in order to see how far the statements are corroborated. Applying this rule of evidence, it will be found that the reviewer, and not the compiler, will suffer. To go no farther than the instances quoted in the text, we find undoubted evidence that the Osages have, within the present century, built both stone heaps and burial mounds; and that if they did not bury in stone graves, the Delawares, Kickapoos, and Shawnees did, and these tribes can be shown to have lived within the region and inside of the time covered by Hunter's narrative. If, now, there were no such individual as Hunter, as the reviewer plainly intimates, then the compiler of the volume that bears his name must have manufactured the story out of whole cloth, which is not probable, or else he must have obtained his information from some person who was cognizant of the existence at some time of this form of burial among the Indians. If, on the other hand, Hunter was a real personage, and the book is a genuine record of his experiences, then the statement must be accepted as true, for the reason that it is not only antecedently very probable in itself, but because the account he has given of the customs of the tribes among whom he clams to have been a prisoner, has not, as yet, been successfully, impugned.

† *Captivity*, p. 309.

earth brought a short distance."* To judge from this description, these graves do not differ from the so-called "stone graves" of Tennessee, and it need not surprise us therefore to hear that although these "Indians do not pretend to any correct knowledge of the tumuli or mounds that are occasionally met with in their country," yet "there are other elevations differing materially from the mounds - - - which were formerly, and are at present, exclusively devoted to burying their dead," and which "are composed of stones and earth, placed in such a manner as to cover and separate one dead body from another,"† precisely as was the case in the stone grave mounds of the Cumberland Valley.‡

Nor is this the only kind of mound that the Osages are said to have erected within the historic period, nor are they the only people of the Dahcotah stock who have been accustomed thus to bury their dead. Featherstonhaugh tells us that upon the unexpected death of one of their chiefs called by the French Jean Defoe, which took place whilst all the men of the tribe were hunting in a distant country, "his friends buried him in the usual manner, with his weapons, his earthern pot, and the usual accompaniments, and raised a small mound over his remains. When the nation returned from the hunt, this mound was enlarged at intervals, every man assisting to carry materials, and thus the accumulation of earth went on for a long period, until it reached its present height, when they dressed it off at the top in a conical form. The old chief further said that he had been informed and believed that all the mounds had a similar origin."§ According to Lewis and Clarke, the Omahas, about the beginning of this century, erected a mound 12 feet in diameter and 6 feet high over the body of their chief, Blackbird,|| and Catlin tells us that at the Red Pipe Stone Quarry can be

* *Captivity*, p, 355. See this and succeeding pages for a description of other modes of disposing of their dead temporarily as well as permanently. Similar stone graves have been found at Augusta, Ky., and, according to Squier (*Abor. Mon. New York*, p. 129), glass beads and iron rings were found in some of them.

† *l. c.*, pp. 307 and 308.

‡ For an account of these graves and mounds, see the *Reports of the Peabody Museum of American Archæology*, etc., vol. II, pp. 305 and 261 *et seq.*: Cambridge, 1880.

§ *Excursion through the Slave States*, pp. 70–71. The old chief further said that "the tradition had been steadily transmitted down from their ancestors, that the Whahsash (Osages) had originally emigrated from the East in great numbers, the population being too dense for their hunting grounds; he described the forks of the Alleghany and Monongahela rivers, and the falls of the Ohio, where they had dwelt some time, and where large bands had separated from them, and distributed themselves in the surrounding country." This mound is probably the same one which Beck (*Gazetteer of Missouri*, p. 308) describes as being "one of the largest mounds in this country, thrown up on this stream within thirty or forty years, by the Osages, near the great Osage village, in honor of one of their deceased chiefs."

|| Lewis and Clarke, vol. I, p. 43: Philadelphia, 1814. Catlin, vol. II, p. 5, visited this mound about 1832, and brought away the skull of the Omaha chief. See his

seen "a mound of a conical form of 10 feet height," which had been thrown up over the body of a distinguished young Sioux, who had been accidentally killed whilst on a visit to that famous spot.*

Crossing the Mississippi, we are told that the Chippewas, an Algonquin tribe, having been successful in a battle with the Sioux, their women and children "in celebrating the achievement, erected a mound from the adjacent surface, about 5 feet in height, and in diameter 8 or 10 feet, upon the summit of which a pole 10 or 12 feet in length was planted, and to this pole tufts of grass, indicating the number of scalps and other trophies achieved, were tied; around this mound the warriors, with their usual ceremonies, indulged in mirth and exultations over the scalps of their fallen foes."† This, it will be noted, is not a burial mound, but seems to have been thrown up to commemorate a victory, and I mention it particularly, as it may serve to shed some light upon the object or purpose for which the so-called anomalous mounds of Mr. Squier were constructed. That some of the Algonquin tribes were however in the habit of erecting mounds over their dead does not admit of a doubt. De Vries (1642—*Voyages*, p, 163: New York, 1853) tells us that the Indians about Fort Amsterdam (New York) "form the grave, 7 or 8 feet, in the shape of a sugar loaf, and place palisades around it;" and in the Jesuit Relations for the year 1611, it is said that the tribes in Maine and farther to the eastward "build a sort of pyramid" over their distinguished dead. According to McKenney, a former superintendent of Indian affairs, the two mounds on Lake Winnebago, Wisconsin, known as Le Grand and Le Petit Butte des Morts, were erected over the bodies of a number of Fox warriors who had been killed in a battle that took place near that spot between that tribe and the Iroquois.‡ Van der Donck, too, as we have seen, is equally positive as

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work for an account of how the mound was built. In *Science* for March 16, 1883, Mr. Frank La Flèche, in a letter to Mr. Putnam, of the Peabody Museum, says: "I made inquiries about the mound made by the Omahas, in which Big Elk was buried, and was told that it was about as high as the shoulders of a tall man standing up, and that he was buried with great ceremonies. His favorite horse was strangled to death by his grave, and most of his horses and household goods were given to the poor." This was about 1825–'30.

* *North American Indians*, vol. II, p. 170: London, 1876. He adds that the story was related to him by the father of the young man, a Souix chief, who was "visiting the Red Pipe Stone Quarry, with thirty others of his tribe, when we were there, and cried over the grave as he related the story."

† S. Taylor, in *Amer. Jour. of Science*, vol. XLIV, p. 22.

‡ From aged Indians "I learned that a long time ago a battle was fought, first upon the spot upon which is Le Petit Butte des Morts, and the grounds adjacent, and continued upon that and the surrounding country, upon which is found Le Grand Butte des Morts, between the Iroquois and Fox Indians, in which the Iroquois were victorious, killing an immense number of the Foxes at Le Petit Butte des Morts; when, being beaten, the Foxes retreated, but rallied at Le Grand Butte des Morts, and fought until they were nearly all slain. - - - In those two mounds, it is said, repose the remains of those slain at those two battles:" McKenney, *Memoirs*, etc., p. 84:

to the erection of burial mounds by certain tribes of this family, and the same fact may be inferred from the account given by Mr. Jefferson * of the opening of a mound that formerly stood on the low grounds of the Rivanna River, and which evidently covered a number of those communal interments of which we have already spoken. This mound was surrounded by a ditch, was about 40 feet in diameter, and had been about 12 feet high, before its height was reduced by cultivation. Trees were growing upon it that measured 12 inches in diameter. It is true that nothing is here said as to the time when, or the people by whom, this mound was built; but the circumstances under which it was revisited by a band of Indians in Mr. Jefferson's time,† taken in connection with the size of the trees, the condition of the bones and the fact that the mound was in close proximity, or "just opposite to some hills on which had stood an Indian town," affords strong evidence that some of the later interments found here must have taken place after the settlement of Jamestown in 1607.

In regard to the practice of the Huron-Iroquois in this respect, our accounts differ. Gen. Parker, in answer to the question whether the Six Nations, after the arrival of the whites, ever erected mounds of earth or stone over single graves, or at their general interments, says positively that he had never heard of the existence of any such custom among them, but that on the contrary they had always asserted that the bone mounds were built by a race of people who had preceded them in the occupancy of the land. He also says that the reasons assigned for the erection of these tumuli, as well as the methods by which they grew to their present size, were always given with great uniformity. This is very high authority, and yet in the present instance it car hardly be regarded as decisive, for the reason that it is negative evidence, and must give way to the positive testimony we have of the fact. Thus for instance Colden, speaking of their single interments, tells us that the Iroquois deposit the body in a large round hole and raise the earth in a round hill over it,‡ and in this he confirms the statements previously quoted of Lafitau and De Vries, the latter of whom (*l. c.*, p. 154), describing the funeral ceremonies of the tribes living near the mouth of the Hudson, tells us that "their manner of living is for the most part

New York, 1846. Other accounts represent this battle as having been fought between the Foxes on one side and the French and Menominees on the other. It is immaterial to me who were the parties engaged against the Foxes.

* *Notes on Virginia*, pp. 186 *et seq.*: Philadelphia, 1801.

† This visit took place about 1750, and is thus described: "On whatever occasion they," the mounds, "may have been made, they are of considerable notoriety among the Indians: for a party passing, about thirty years ago through the part of the country where this barrow is, went through the woods directly to it, without any instructions or inquiry; and having staid about it some time, with expressions which were construed to be those of sorrow, they returned to the high-road, which they had left about half a dozen miles to pay this visit, and pursued their journey:" *Ib.*, p. 191.

‡ *Five Nations*, Introduction, p. 16.

like that of those at Fort Orange; who however are a braver and a more martial nation of Indians—by name, the Maquas—as before mentioned, and who hold most of the others along the river to Fort Amsterdam under tribute."

Of the bone mounds, or those which mark the site of one or more communal interments, our accounts, though somewhat meager, are not less explicit. According to La Fort, the Onondaga chief, different forms of burial existed among the Iroquois at different times, and he might also have added at the same time, when the conditions were different. Thus, in addition to the mode of interment already noticed, we are told that when numbers were slain in battle they "were gathered and laid in tiers one above another, and a high mound raised over them."* In partial confirmation of this, we have the statement of the Modern Senecas that the mound on Tonawanda Island was the burial place of the Neuters,† a kindred tribe, who were destroyed by the Iroquois about the middle of the seventeenth century; and there is also the mound visited by the Rev. Mr. Kirkland in 1788, and though the condition of "the bones upon its surface, and sticking out in many places on its sides," is totally incompatible with any such antiquity as is claimed for it, yet there can be no reason why the account given by the Senecas of the circumstances under which it was built may not be literally true. Especially is this so, in view of the fact that we have undoubted evidence that at a council, held in 1743, between the Onondagas and the Anticoque Indians, the latter "gave broad belts of *wampum*, 3 arm belts and 5 strings; one was to wipe clean all the blood they had spilt of the *Five Nations*, another to raise a tumulus over their graves, and to pick out the sticks, roots, or stones, and make it smooth on the top."‡ This is believed to be decisive of the matter, for construe the statement as we may, there can be no doubt that the Iroquois, or the people with whom they fought, were in the habit of building mounds over their dead; and, so far as my argument is concerned, it is perfectly immaterial which of them did so, as the question is not what particular tribe constructed these mounds, but were they built by the red Indians of historic times?

South of the Ohio, in the States along the Atlantic coast, certain tribes are said to have had the same custom. Lawson, describing the manner of interment among the Santees, one of the Carolina tribes, says: "A mole or pyramid of earth is rais'd, the mould thereof being work'd very smooth and even, sometimes higher or lower according to the dignity of the person whose monument it is. On the top thereof is an umbrella, made ridge-ways, like the roof of an house; this is supported by nine stakes, or small posts, the grave being about six or

* J. V. H. Clark, *Onondaga*, vol. I, p. 51.

† Marshall, *Historical Sketches of the Niagara Frontier*, p. 8.

‡ John Bartram, *Observations*, etc., p. 62: London, 1751.

eight foot in length and four foot in breadth."* In Florida proper we are told that upon the death of a king he was buried with great solemnity, and the shell from which he usually drank was placed on the tumulus, around which many arrows were stuck up. Le Moyne† gives a picture of one of these graves—shell, arrows, and all—but either the drawing is most abominably foreshortened, or else the tumulus is too insignificant to come within the scope of our inquiry. However, both this and the preceding interment belong to the class called single, and this may perhaps account for the size of the mounds erected over them. In each of the localities referred to the communal form of burial was also practiced, and in some cases, especially on the peninsula, mounds covering interments of this character have been found, which are not only of large size,‡ but which, from the nature of their contents, must have been thrown up after the arrival of the whites. That the tribes inhabiting the Gulf States, including under this head the Chickasaws, Cherokees, Choctaws, and the Muscogees and their allies, were at one time in the habit of erecting mounds over their dead does not admit of a doubt, though it is probable that the custom, like many others connected with their funeral rites, died out at an early day.

Adair tells us that "many of these heaps are to be seen in all parts of North America; where stones could not be had, they raised large hillocks or mounds of earth, wherein they carefully deposited the bones of their dead, which were placed either in earthen vessels or in a simple kind of ark chests."§ According to De Brahm, "A large conical mound near Savannah was pointed out to Gen. Oglethorpe as being the tomb of the Yamacraw chief, who had, many years before, entertained a great white man with a red beard;"‖ and the evidence of the younger (William) Bartram, to which we have so often had occasion to refer, is even more definite. Describing the burial customs of the Choctaws, that writer says: "As soon as a person is dead they erect a scaffold 18 or 20 feet high in a grove adjacent to the town, where they lay the corpse, lightly covered with a mantle; here it is suffered to remain, visited and protected by the friends and relatives, until the flesh becomes putrid, so as easily to part from the bones, then undertakers, who make it their business, carefully strip the flesh from the bones, wash and cleanse them, and when dry and purified by the air, having provided a curiously-wrought chest or coffin, fabricated of bones and splints, they place all the bones therein, which is deposited in the bone-house, a building erected for that purpose in every town. And when

* *History of Carolina*, p. 21.

† De Bry, plate xl.

‡ *Narrative of Osceola*, quoted by Dr. Brinton in the *American Antiquarian* for October, 1881.

§ *Hist. of Amer. Indians*, note to p. 185.

‖ Quoted in *Antiquities of the Southern Indians*, p. 131.

this house is full a general solemn funeral takes place. When the nearest kindred or friends of the deceased, on a day appointed, repair to the bone-house and take up the respective coffins, and following one another in order of seniority, the nearest relations attending their respective corpse, and the multitude following after them, all as one family, with alternate voice of Allelujah and lamentation slowly proceeding on to the place of general interment, where they place the coffins in order, forming a pyramid; and lastly, cover all over with earth, which raises a conical hill or mount."*

The third and last class of mounds that we shall consider are the truncated, or, as they are sometimes called, temple mounds, with graded ways to their tops. They are comparatively numerous south of the Ohio, and are also found, though less frequently, as far north as the middle of the tier of States that lie along the northern bank of that river; but beyond this point they are believed to be unknown. Of their origin and use in the Southern States, and especially along the line of De Soto's march, there is abundant proof. The chroniclers of that enterprise are in full accord upon these points; and though it is not possible to make out the itinerary of that expedition, yet there is but little hazard in asserting that he was on both sides of the Mississippi, and visited not only the Muscogees and Choctaws of the Gulf States, but also the Cherokees ("Achalaqué") and Chickasaws of Tennessee, and the Quapaws (Capahas-Kappas) of northeastern Arkansas. Among all these tribes there was a general uniformity in the methods of building the cabins of their chiefs, and in laying out and fortifying their villages. La Vega† tells us that the town and house of the Cacique Ossachile were like those of all the other Caciques in Florida, and assigns this as the reason why, instead of describing this particular town and house, it was better to give one general account that would answer for all. He then goes on to say that the Indians always endeavor to place their villages on elevated sites; but as such situations, with the conveniences for building, are not always to be found in Florida, "they themselves throw up elevations in this manner. They choose a spot to which they bring a quantity of earth, and this they pile up in the shape of a platform, two or three pike's length in height, and large enough on top to hold ten or twelve, fifteen or twenty houses, in which are lodged the Cacique and his attendants. At the foot of this mound they lay out a square, proportioned to the size of the intended town,

* *Travels through Florida*, p. 516. On p. 139 he speaks of "sepulchres or tumuli of the Yamasees, who were here slain by the Creeks in the last decisive battle, the Creeks having driven them to this point, between the doubling of the river, where few of them escaped the fury of the conquerors. These graves occupied the whole grove, consisting of 2 or 3 acres of ground; there were nearly thirty of these cemeteries of the dead, nearly of an equal size and form; they were oblong, 20 feet in length, 10 or 12 feet in width, and 3 or 4 feet high, now overgrown with orange trees, live oaks," etc.

† *Histoire de la Floride*, première partie, livre 2de, chap. xxvii: Paris, 1709.

and around this the principal men of the village build their cabins. The common people are housed in the same manner, and thus they surround the dwelling of their chief." To ascend this elevation they have a graded way from top to bottom, in which the slope is so gradual that a horseman can ride up without any difficulty. Excepting at this one place, all the other sides are made so steep as to be difficult of ascent. Elsewhere, in the town of Guachoule, on the head waters of the Coosa River,* and near the country of the "Achalaqué," the dwelling of the chief is said to stand on a "mound, with a terrace around it wide enough for six men to walk abreast."† West of the Mississippi, among the Capahas and their neighbors, it was the custom of the Caciques to raise "near their dwellings very high hills, on which they sometimes build their huts;"‡ and the Gentleman of Elvas tells us that in the town of Ucita, near which De Soto landed, and which is supposed to have been situated on the west coast of Florida, "the lord's house stood upon a very high mount, made by hand for strength."§ A few years later, in Laudonnière's account of the ill-fated attempt of the Huguenots to plant a colony on the northeastern coast of this same Floridian peninsula, we have repeated allusions to "alleys,"‖ which are none other than the "grand avenues" or Indian highways, mentioned by Bartram as leading in a straight line from "a pompous Indian mount, or conical pyramid of earth, that stood on the site of an ancient town, through a magnificent grove of magnolias, live oaks, palms, and orange trees, to the verge of a large green level savanna."¶

Passing over an interval of one hundred and fifty years, we find that, among many of these same tribes, the custom still existed of erecting mounds as sites for their habitations. The cabins of the Yazous, Courois, Ossagoulas, and Ouspie tribes, living on the lower Mississippi, are said to have been "dispersed over the country upon mounds of earth made with their own hands, from which it is inferred that these nations are very ancient, and were formerly very numerous, although at the present time they hardly number 250 persons."** According to Du Pratz, the temple of the Natchez was about 30 feet square, and was situated by the side of a small river, on an artificial mound, which was about 8 feet high, and sloped insensibly from the main front on the north, but was somewhat steeper on the other sides." The same author also tells us that the cabin of their chief, or Great Sun, as he was called, was placed upon a mound of about the same height, though it was somewhat larger, "being 60 feet over on the surface."†† When

* Picket, *History of Alabama*, vol. I, p. 8: Charleston, 1851.

† La Vega, seconde partie, p. 2.

‡ Biedma, *Hist. Coll. Louisiana*, part II, p. 105.

§ *Gentleman of Elvas*, *l. c.*, p. 123.

‖ Hakluyt, vol. III, pp. 407 and 415.

¶ *Travels through Florida*, pp. 103 and 521.

** La Harpe, in *Hist. Coll. Louisiana*, part III, p. 106.

†† *History of Louisiana*, vol. II, pp. 211 and 188.

a chief died, these people demolished the cabin in which he had lived, and raised a new mound, upon which they placed the dwelling of his successor, as it was not customary for a chief to lodge in a house that had been previously occupied.*

Whether the Natchez erected the immense works found on the Washita River, near the outlet of Lake Catahoula, is a point about which opinions may well differ. That they took refuge in the immediate neighborhood of these works, if not on their very site, after the destruction of their village on the Mississippi, and "built a fort," according to Du Pratz, or "fortified themselves," as Charlevoix states, is beyond question; but Judge Force,† who has examined into the matter very thoroughly, is of the opinion that they were not permitted to hold this position long enough to have constructed works of the size of those found here. In this he is believed to be correct, though of course it would all depend upon the number of those who had sought refuge on this spot, and the earnestness with which they worked. As some indication of the time necessary to the erection of works of this character, the following fact, for which I am indebted to Lieut. Commander A. R. McNair, U. S. Navy, will be of interest. According to that gentleman, upon one occasion in 1863, when coaling at the island of St. Thomas, 150 negro laborers easily brought on board of the Powhatan, in twelve hours, 100 tons of coal, using only baskets for that purpose. Allowing 40 cubic feet to the ton, this would give a cube of coal, measuring 20 × 20 × 10 feet, moved in one day by 150 men; and with this as the basis for a calculation, it will be seen that the length of time absolutely necessary to the construction of these works is not so great as might be supposed.‡ However, this is a point upon which it is need-

* Father Le Petit, quoted in *Hist. Coll. Louisiana*, part III, note to p. 142.

† *Some considerations on the Mound-builders*, p. 77, and note B: Pamphlet, 1873. Stoddard, *Sketches of Louisiana*, p. 350, speaking of the size of these works, says: "Not less than five remarkable mounts are situated near the junction of the Washita, Acatahoula, and Tenza, in an alluvial soil. They are all inclosed in an embankment or wall of earth, at this time 10 feet high, which contains about 200 acres of land. Four of these mounts are nearly of equal dimensions, about 20 feet high, 100 broad, and 300 long. The fifth seems to have been designed for a tower or turret; the base of it covers an acre of ground; it rises by two stages or steps; its circumference gradually diminishes as it ascends; its summit is crowned by a flattened cone. By admeasurement, the height of this tower is found to be 80 feet.

‡ Strongly confirmatory of this view is the following extract from Isaac McCoy's *History of the Baptist Indian Missions*, etc., p. 27: "A little reflection will show that the amount of labour required in their erection did not surpass the common industry of the savages. Suppose a mound to be 40 feet in diameter at its base, and to rise by steps, 1 foot in height and a foot and a half in depth, to the height of 13 feet, with a level surface on the summit 4 feet in diameter. It would contain about 6,233 cubic feet of earth, or a fraction less than 231 cubic yards. To deposite on the mound 1 cubic yard of earth would be a moderate day's labour for 1 man. Therefore, the erection of the mound under consideration would employ 231 persons *one day only*. Among the Indians, the women would perform as much of this kind of work as the men, or perhaps more, and more than twice this number of persons able to labour

less to insist, as the evidence is quite sufficient to show that the Natchez did build both mounds and earth-works. Du Pratz states the fact positively,* and although it can not be proved that they threw up the embankment and other works on the Wachita, yet there is unquestionable authority for the statement that a short time after the destruction of their stronghold here by the French under Perier, a band of them, which had managed to escape the general ruin, made an attack upon the post of Natchitoches, during the course of which they were driven back, and obliged to "dig a kind of entrenchment on the plain."†

Among the Creeks and their allies, even as late as 1773–'75, we are told that almost every town had a "chunk yard," surrounded by one or two low embankments or terraces, in the center of which, on a low circular mound or eminence, stood a four-square pole or pillar, 30 or 40 feet high, to the top of which was fastened some object that served as a mark to shoot at, with arrows or the rifle, at certain appointed times. At one end of this yard, which was usually from 600 to 900 feet in length and of proportionate breadth, was a square terrace or eminence 9 or 10 feet high, "upon which stood the public square," and at the other extremity was a circular mound of about the same height, which served as a site for their rotunda or winter council house.‡ The Cherokees too, as we have seen, utilized this class of mounds in much the same manner, the council house in their town of Cowe, according to the same author, occupying the summit of one that was said to have been 20 feet high. If now we compare the method of laying out these towns, and building the temples and council houses of these later Indians with that described by La Vega, as having been followed by their ancestors a century and a half earlier, it will be seen that the resemblance is very great; and although we are sometimes assured that the modern Creeks and Cherokees could give no account of the origin or purpose of these earthen structures, yet there can be no doubt that in Bartram's time these

are frequently at one village or one encampment. - - - Within the Indian Territory we have 94,000 inhabitants; one-fifth of these, or more, are competent to labour. This gives 18,800 labourers; if each of these would, in the course of twelve months, bestow only as much labour on the erection of mounds as would amount to one day, 81 mounds would be built in one year." Washington and New York, 1840.

* Besides the statements quoted in the text, he says: "Le pied des pieux est appuyé en dedans par une banquette de trois pieds de laarge, and autant de haut, laquelle est elle-même appuyée de piquets frettés de brancages verds, pour retenir la terre qui est dans cette banquette:" *Histoire de la Louisiane*, vol. II, p. 435; Paris, 1758.

† Dumont, *Mémoires Historiques de la Louisiane*, tome II, p. 200, says "Creuserent dans la plaine une espèce de retranchement où ils se fortifierent." Charlevoix (*Nouvelle France*, vol. IV, p. 293) uses the word "retranchés."

‡ Bartram, MSS. published in *Anc. Mon. Miss. Valley*, p. 121. Adair, *l. c.*, p. 421, tells us that "every town has a large edifice, which, with propriety, may be called the mountain house. - - - It is usually built on the top of a hill; and in that separate and imperial statehouse the old beloved men and head warriors meet on material business, or to divert themselves, and feast and dance with the rest of the people."

tribes lived much as their fathers had done before them; and if they did not build the mounds and chunk yards found in their midst they, at least, used them for the same purposes for which they were originally erected.*

*Inclosures.*—Of the manner in which the nations east of the Mississippi fortified their villages our accounts are full and explicit. Palisades, as has been shown, were employed everywhere; but as this term, alone, fails to give an adequate idea of the methods by which the Indians were accustomed to defend their more exposed villages, it may be well to go into the matter somewhat in detail. To this end it will be necessary again to resort to the early chroniclers; and although this may prove tedious, yet it is unavoidable, as it is only by a study of the manner of fortification practiced by the recent Indians that a clue can be found to the mystery that surrounds the Ohio system of earthworks, to which we now must refer. Of the origin of these we are without any written record whatever unless the traditions of the Delawares, Iroquois, and Natchez, as related by Heckewelder, Rafinesque, Cusick, and Du Pratz,† should be accepted as such. This is of course rather a serious obstacle to be met with at the outset of an investigation; but fortunately, in the present instance we have not far to go in order to discover a reason for the seeming omission. It may be found in the fact that after the destruction of the Eries, say about the middle of the seventeenth century, the whole of that region now known as the States of Ohio and Indiana was virtually deserted, and so remained for upwards of fifty years. Iroquois war parties swept undisturbed from the Niagara River to the Illinois, and whilst there may have been villages of the Twightwees (Miamis) and their allies scattered about here and there, yet practically that whole section of country was a solitude, unvisited by the trader, the soldier, and the no less venturesome missionary, the only persons who could, in those early days, have given us an account of what they saw and heard.

Of the tribes that may possibly once have lived here, the Shawnees‡

* Bartram, *Travels*, etc., p. 520.

† For the traditions of the Delawares consult chap. v of *The American Nations*, by Prof. C. S. Rafinesque: Philadelphia, 1836. Du Pratz, vol. II, p. 146 (London, 1763), speaking of the Natchez, says: "To give an idea of their power I shall only mention that formerly they extended from the river Manchac or Iberville, which is about 50 leagues from the sea, to the river Wabash, which is distant from the sea about 460 leagues; and that they had about 500 *suns* or princes. From these facts we may judge how populous this nation formerly has been; but the pride of their *great suns* or sovereigns, and likewise of their inferior *suns*, joined to the prejudices of the people, has made greater havoc among them and contributed more to their destruction than long and bloody wars would have done." In the above extract he refers to the practice of human sacrifices upon the occasion of the death of any of the *suns* or chiefs.

‡ "The countries and rivers of Ohio and Wabasche and circumjacent territory were inhabited by our Indians, the Chaouanons, Miamis, and Illinois:" Memoir sent by the King to Mr. Denonville, Gov. Gen. of New France, in *Hist. Coll. of Louisiana*,

were now a broken and a scattered people, and the Miamis had been forced back until we find them seeking shelter under the guns of the French fort on the Illinois.* Such then being the condition of affairs throughout this portion of the Ohio Valley during the latter part of the seventeenth and the beginning of the eighteenth centuries, there was nothing to tempt the trader, or attract the missionary; and hence the absence of all mention of this region, save in the occasional notices of an Iroquois foray, or of the spasmodic attempts of their enemies at retaliation. Later on, about the middle of the last century, the above-mentioned tribes are found once more established within this region, having apparently retraced their steps. The Miamis are in western Ohio and northern Indiana, and the Shawnees of the Delaware, having been driven across the mountains, re-unite with their kindred from Georgia, and are settled in the valley of the Scioto, where singularly enough their villages are in the immediate neighborhood, if they do not occupy the very sites, of the famous mound centers of Chillicothe and Portsmouth.† Indeed, we are told that about A. D. 1750, at this latter point, their village was situated on both sides of the Ohio River,‡ just as is the case with the mounds and embankments found there to-day.

Of course it is not pretended that all the works in these valleys were erected subsequent to this date, and it is quite probable that not one of those of large size was, but that some of them were built after the arrival of the whites, a hundred and fifty or two hundred years earlier, is proved by the contents of mounds opened at Circleville and Marietta; and that these same Indians, or their immediate descendants, have within comparatively recent times "encompassed their villages with ditches and walls," as well as palisades, is evident from the account

new series, 1875, p. 137. "Formerly, divers nations dwelt on this river"—Hohio—"as the Chawanoes (Shawanees), a mighty and very populous people, who had above fifty towns, - - - who were totally destroyed or driven out of their country by the Irocois, this river being their usual road when they make war upon the nations who lie to the South or to the West:" Coxe's Carolina, in *Hist. Coll. Louisiana*, part II, p. 229. For an account of all that is known historically of the wanderings of the Shawnees, see Judge M. F. Force, *Some Early Notices of the Indians of Ohio:* Pamphlet, Cincinnati, 1879.

*Tonti, in *Hist. Coll. Louisiana*, part I, p. 66. "The Iroquois, after expelling the *Hurons* and exterminating the *Eries*, who inhabited the country bordering on the Great Lakes, which now bear their names, events which happened about the years 1650 to 1660, took possession of their vast territory, and retained it for more than a century after. Their hunting country, which they once occupied, is now embraced in the State of Ohio, and while in their possession was called Carrahague:" Appendix to *Morse's Report*, p. 60. At the treaty of Fort Stanwix, in 1768, they sold all that region of country now known as the State of Kentucky, claiming it by right of conquest: See Butler's Kentucky, p. 378: Louisville, 1834.

†Schoolcraft, *Indian Tribes*, vol. VI, p. 277. Croghan, *Journal*, in Appendix to Butler's *Hist. of Kentucky*, p. 462: Cincinnati, 1836.

‡Christopher Gist's *Journal*, in Appendix to Pownall's *Topographical Description*, p. 10: London, 1776. See also Croghan's *Journal*.

Schoolcraft has left us of his visit to Prophetstown, on the Tippecanoe, and to the sites of other Indian villages in Indiana and Illinois.* These facts are undoubtedly of importance in indicating the phase of civilization that had been reached by the builders of some—perhaps the smaller and more recent—of these works; but they do not enable us to connect even inferentially those of the larger size with any particular tribe, owing to the fact that there was such a long interval of time, when Ohio, so far as we know, was virtually uninhabited. If it were possible to show that previous to the settlement of the Iroquois in western New York a Shawnee confederacy had occupied the Ohio Valley, as Rafinesque † so confidently asserts, our task would be much simplified. It would then be apparent that in returning here these people were but reoccupying their old homes and hunting grounds; and as they can be shown to have defended themselves within comparatively recent times behind ditches and breast-works,‡ and as they must from the necessities of the case have erected all the mounds that were built within that region subsequent to the landing of the whites, there would certainly be nothing forced or illogical in the inference that they had constructed the older and larger series of works during the palmy days of their confederacy, some hundreds of years before the time of which we are now speaking. Unfortunately however Rafinesque fails to make good his statement; and though the evidence, drawn from other sources, bearing upon this point is sufficient to furnish the basis for a very plausible theory, yet it does not afford a satisfactory foundation for an inductive argument, and hence it is altogether omitted.

For these reasons, then, we are without any historical evidence as to the origin of the works in the northern part of the Ohio Valley, and as there is no probability that any will ever be discovered, we are obliged to fall back upon the comparative method in order to see whether there are any such differences between the hill forts and fortified villages of southern Ohio and those found in western New York and in some of the Southern States as would authorize the inference that they were the work of a people in a different stage of civilization.

Beginning with the "forts," as Governor DeWitt Clinton § calls them, of western New York, we are told that they were generally speaking erected upon the most commanding ground, and were surrounded,

* Schoolcraft, *Travels in Central Portion of the Mississippi Valley*, pp. 129, 323.

† Refinesque, *Ancient Annals of Kentucky*, p, 25: Frankfort, 1824.

‡ Gist, in p. 12 of the Appendix to Pownall's *Topographical Description of Parts of North America*, London, 1776, speaks of a "fort" of the Twightwees; and Croghan, in 1765, found a "breastwork" near the mouth of the Wabash, which, in one account, is "supposed" to have been erected by the Indians; but in another the fact is stated positively.

§ This account is made up from Clinton's Discourse in *Collections of the N. Y. Hist. Soc.*, vol. II, p. 90; Squier, *Aboriginal Monuments of New York;* Moulton, *History of New York*, vol. I, part I; Clark's Onondaga, etc., etc.

either wholly or in part, by ditches and earthen walls. The palisades that once stood on some of these embankments* had long since rotted away, and in their places were growing oak trees which, from the number of concentric circles, must have been three hundred years old; and there were evident indications, not only that they had sprung up since the erection of these works, but that they were at least a second growth. The trenches were, in some cases, deep and wide, and in others shallow and narrow; and the breastworks varied in height from 3 to 10 feet. In one case near Elmira they are said to have been 14 feet wide at the base.† There were one or more entrances to these forts, from one of which a "covered way" sometimes led to the water.‡ The form of these inclosures was determined by the nature of the ground; and in area they varied from 2 to 6 acres, though occasionally they were much larger, as, for instance, the one near Livonia, N. Y., which contained 16 acres,§ and the one 14 miles from Sacketts Harbor, which, according to Moulton, "covers 50 acres."‖ That they were very numerous is evident from Squier's estimate, placing them at from 200 to 250;¶ and as they seem to have made up in number what they lacked in size, it is equally evident that taken in mass the amount of labor involved in their construction must have been immense. It would be a grave mistake however to regard this as a measure of the populousness of this region, since it probably resulted from the custom of the Indians of changing their village sites every "ten, fifteen, or thirty years," or in fact whenever the scarcity of fire-wood, the exhaustion of their fields, or the prevalence of an epidemic made such a step desirable.**

This is a brief general description of these inclosures as they appear to-day; and if we compare them with the "defensive works" as depicted in Ancient Monuments of the Mississippi Valley, it will be seen that they are very like those along the southern shore of Lake Erie, as well as the smallest of those in the Ohio Valley; and that they do not differ, except in size, from those found in the same valley, which are usually ascribed to the mound-builders. In situation, form, and structure they are the same, and as both were covered with heavy forests, there can be no difference urged between them upon the score of antiq-

* MSS. of Prof. E. N. Horsford in *Abor. Mon. of New York*, p. 38.

† *Abor. Mon. of New York*, p. 38.

‡ Kirkland MSS. quoted in Moulton, New York, pp. 16 and 17. In one case he speaks of a "covered way in the middle of a stockade down to the water;" in the other he says, "a way was dug to the water."

§ *Abor. Mon. of New York*, p. 44.

‖ *l. c.*, p. 15.

¶ *Abor. Mon. of New York*, p. 11. Compare Moulton, p. 18, who says that on the south side of Lake Erie, for a distance of 50 miles, "is a series of old fortifications, some of which are from 2 to 4 miles apart, others half a mile only."

** Sagard, *Voyage des Hurons*, tome I, p. 81: Paris, 1865. La Vega, I, p. 265: Paris, 1709.

uity. The relics, too—especially the implements and ornaments of stone, bone, and shell—that are found under similar circumstances within or near these two series of works are identical in form and finish; and the best specimens of the Iroquois black pottery, described by Morgan* as being of various designs and sizes, and of such "fine texture as to admit a tolerable polish, and so firm as to have the appearance of stone," can not have been very different from the same class of articles that have been taken from the mounds in the Ohio Valley. Indeed Mr. Squier† says that the terra cottas of western New York compare favorably with anything he had yet seen of native workmanship; and that the earthen pipes, said by Morgan to be nearly as hard as marble, fancifully molded in the form of animals and of the human head, are so "hard, smooth, and symmetrical as almost to induce doubts of their aboriginal origin."

In view of these manifold resemblances, too numerous and too close to have been the result of accident, it behooves us to inquire into the origin of the earth-works in western New York. According to Mr. Squier‡ they were, one and all—mounds as well as embankments—"erected by the Iroquois or their western neighbors;" and he bases this opinion upon a comparison of the "relics and traces of occupancy" that are found within these abandoned inclosures with those which mark the sites of towns and forts that are known to have been occupied by the recent Indians. These he declares to be identical, as is also their pottery, whilst their pipes and ornaments are said to be indistinguishable. "The indications of aboriginal dwellings are precisely similar, and, so far as can be discovered, have equal claim to antiquity. Near many of these works are found cemeteries, in which well-preserved skeletons are contained, and which, except in the absence of European

* *League of the Iroquois*, p. 354. The Indians everywhere east of the Mississippi and south of the lakes had made great progress in the manufacture of earthenware. Thus we are told that "the Roanoke Indians have earthen pots, large, white, and sweet:" Hakluyt's *Voyages*, III, p. 304. The Creeks, Chickasaws, etc., "make earthen pots of very different sizes, so as to contain from 2 to 10 gallons; large pitchers to carry water; bowls, dishes, platters, basins, and a prodigious number of other vessels of such antiquated forms as would be tedious to describe and impossible to name. Their method of glazing them is, they place them over a large fire of smoky pitch pine, which makes them smooth, black, and firm:" Adair, p. 425. Among the Natchez these vessels were "d'un assez beau rouge:" Du Pratz, II, p. 179: Paris, 1758. "The Naudowessies make black pottery nearly as hard as iron:" Carver, pp. 101–223. West of the Mississippi, at Naguatex, there are vessels made of clay which differ very little from those of Estremoz and Montremor:" Knight of Elvas in *Hist. Coll. Louisiana*, part II, p. 201. In *Ancient Society*, note to p. 530. Morgan, on the authority of Mr. F. A. Cushing, tells us that "the Iroquois ornamented their jars and pipes with minature human faces attached as buttons;" and as this style of ornamentation is believed to be somewhat unusual, it may be well to say that, in the Peabody Museum at Cambridge, there are several bowls of black pottery, from stone graves in Tennessee, which are ornamented in this manner.

† *Abor. Mon. of New York*, p. 13 and chapt. v.

‡ *l. c.*, p. 82.

art, differ in no essential respect from the cemeteries found in connection with the deserted modern towns and 'castles' of the Indians." This is certainly a very strong statement of the case, and if we add that the Huron-Iroquois were accustomed to fortify their forts or castles with a ditch and wall, the latter surmounted by a stockade, it will be seen that Mr. Squier had good and sufficient reasons for attributing all these works to the recent Indians. Indeed, now that the palisades that once inclosed the villages known to have been occupied by the Iroquois have rotted away, there is no structural difference to be seen between them and any of the earthworks of western New York; and as these, in their turn, are identical in this respect with the hill forts of the Ohio Valley, it must follow, if the Iroquois or their western neighbors erected the New York series of these works, that there is no reason why these same western neighbors, or a people in the same stage of civilization, could not have built those in Ohio and still further to the west, due regard being had to their population and to the necessity for such defenses. Thus for instance whilst a weak or peaceful tribe, in the midst of enemies, would find it necessary to fortify themselves at every point, a strong and warlike people, of whom their neighbors stood in awe, would be relieved of this necessity, except in the direction from which they anticipated danger. This was forcibly exemplified in the case of the Iroquois,* when in the heyday of their power; and it may still be seen in New Mexico, where the Pueblo of Taos is, or was until very lately, "surrounded by an adobe wall, strengthened in some places by rough palisades,"† whilst their more warlike neighbors, like the Apache and the Navajo, have not found such defenses necessary or even desirable.

Of the method practiced by the Huron-Iroquois of fortifying their villages, our accounts are very full and explicit. Parkman,‡ whom it is safe to follow, in an admirable sketch of the Hurons, tells us that the defenses of this family of tribes, "like their dwellings, were, in essential points, alike. A situation was chosen favorable to defense—the bank of a lake, the crown of a difficult hill, or a high point of land in the fork of confluent streams. A ditch several feet deep was dug around the village, and the earth thrown up on the inside. Trees were then felled by an alternate process of burning, and hacking the burnt part with stone hatchets, and by similar means were cut into lengths to form palisades. These were planted on the embankment in one, two, three, or four concentric rows," the whole being crossed and interlaced after the manner of a chevaux-defrise, and lined within to the height of a man with heavy sheets of bark. At the top, where the palisades crossed, was a gallery

* Morgan, p. 314.

† Bancroft, *Native Races of the Pacific States*, vol. I, p. 664.

‡ *Jesuits in America*, p. xxix of the Introduction: Boston, 1874. Compare Morgan, p. 314; Lafitau, vol. II, pp. 3 *et seq.*; Sagard, *Voyage des Hurons*, pp. 79–80: Paris, 1856.

of timber for the defenders, together with wooden gutters, by which streams of water could be poured down on fires kindled by the enemy. There was no mathematical regularity in these works, their form being determined by the nature of the ground. Frequently a precipice or river sufficed for partial defense, and the line of embankment occurs only on the exposed sides. We are also told that in erecting these works it was probable that the palisades were planted first, and the earth afterwards heaped on both sides in the manner described by Cusick * and La Hontan.† At an early day the Jesuits taught the Hurons to build rectangular palisaded forts with bastions, and the Iroquois, whose forts are said to have been stronger and more elaborate than those of the Hurons, soon adopted the same practice, omitting, in some cases, the ditch and the embankment. Among the Algonquin tribes of southeastern New York a similar method of fortification seems to have prevailed. According to Van der Donck,‡ the Indians of New Netherlands, "in their villages and castles always build firm, strong works. They usually select a situation on the side of a steep, high hill, near a stream or river, which is difficult of access except from the water, and inaccessible on every other side, with a level plain on the crown of the hill, which they inclose with a strong stockade in a singular manner. First they lay along on the ground large logs of wood, and frequently smaller logs upon the lower logs, which serve for the foundation of the work. Then they place strong oak palisades in the ground on both sides of the foundation, the upper ends of which cross each other, and are joined together. In the upper cross of the palisade they then place the bodies of trees, which makes the work strong and firm. These castles are considered very strong, and they frequently contain twenty or thirty houses, some of which, by actual measurement, are 180 yards (*sic*) long, and about 20 feet wide. Besides these strongholds they have other villages and towns, which are also inclosed."

The Pequots of Connecticut were a kindred tribe, and Vincent,§ describing their fort near New London, says: "Here they pitch, close together as they can, young trees and half trees as thick as a man's thigh or the calf of his leg. Ten or twelve foot high they are above the ground, and within rammed 3 foot deep with banking, the earth being cast up for their better shelter against the enemy's dischargements." A fort of the Narragansetts is said to have had an exterior ditch,‖ and we are told that a party of Mohegans, having invaded Block

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* In vol. v of Schoolcraft, *Indian Tribes*, p. 637.

† *Travels*, vol. II, p. 67: "The Hurons set up pales and fasten them with earth." "The Indians are more skillful in erecting their fortifications than in building their houses; here you see villages surrounded with a good palisade and with redoubts:" Charlevoix, *Letters*, ii, p. 127: London, 1761.

‡ *New Netherlands*, p. 197.

§ *Mass. Hist. Coll.*, third series, vol. VI, p. 39.

‖ Dwight's *Travels*, vol. III, p. 23: New Haven, 1822.

Island, were driven to a high bluff and starved to death, though not until they had found means to "dig a trench around them, toward the land, to defend them from the arrows of their enemies."* In 1637 the Algonquins, living at Trois Rivières, Canada, being alarmed at the rumor of an Iroquois attack, strengthened their fort by erecting a second row of palisades, distant from the first about a foot and a half, and filling the intervening space with fascines and earth.† According to Charlevoix, the Outagamis (Foxes), in 1712, made an attack upon the French post at Detroit, and having been repulsed, took refuge in a fort where they were well entrenched (*retranchés*). The fire upon them, however, was so steady that they were obliged to get into a ditch 4 or 5 feet deep (*se mettre a quatre oŭ cinq pieds en terre*). Taking advantage of a lull in the firing, they made themselves masters of a house that was left standing near their fort and raised a redoubt (*redoute*).‡ Being eventually driven from this stronghold, they retired to a peninsula that jutted into the lake, where, to the number of five hundred men and three thousand women and children, they shut themselves up in a fort, surrounded by "three rows of oak palisades with a deep ditch behind."§ Elsewhere, as we have seen, tribes in Illinois and Indiana belonging to this same family have defended themselves in a similar manner within comparatively recent times; and in the narrative of Conrad Wiser, the interpreter, we are told of a place in Pennsylvania where "the Indians, in former times, had a strong fortification on a height. It was surrounded by a deep ditch; the earth was thrown up in the shape of a wall, about 9 or 10 feet high, and as many broad. But it is now (1741) in decay, as from appearance it had been deserted beyond the memory of man."‖

In Virginia the Indians, according to Capt. Smith, had "pallizadoed towns, mantelled with the barkes of trees, with scaffolds like mounts."¶ There is no mention of a ditch or of an embankment, and as a rule there seems to have been but one row of palisades, though when they would be very safe "they treble the pales." Sometimes they "encompassed their whole town, but for the most part only their kings' houses, and as many others as they judge sufficient to harbor all their people, when the enemy comes against them."** This mode of defense was kept up in Carolina until the final expulsion of the Indians, as we are told that the Tuscaroras (1712–'13) built their forts in this manner, and upon one occasion, when besieged by the whites, they refused to surrender until

* *Mass. Hist. Coll.*, third series, vol. VI, p. 197.

† Le Jeune, *Relation*, 1637, p. 83. In the original it reads: "Avec dessein de remplir ce vuide de fascines et de terre."

‡ *Nouvelle France*, vol. IV, pp. 97 and 98.

§ *Ibid.*, p. 156.

‖ Published in vol. IV, Schoolcraft, *Indian Tribes*, p. 326.

¶ Purchas *Pilgrims*, vol. IV, p. 1715.

** Beverly, book III, p. 12.

cannon were planted within a few yards of their walls.* In the States still farther to the south, the same method of fortification was practiced. Le Moyne, the artist of Laudonnière's expedition, gives a picture of one of these villages,† which is surrounded by a single row of palisades, twice the height of a man, set close together. The entrance is narrow, drawn in after the manner of a snail shell, and is further defended by two small round buildings, with slits and holes for observation, something like an old-fashioned sentry box.

In the Gulf States, including under this head portions of Tennessee and Arkansas, the Indians have been in the habit of fortifying their vilages with ditches and stockades from the time of De Soto down to the beginning of the present century. As late as 1814 the position of the Creeks, at the battle of the Horseshoe, is said to have been protected by a line of earth-works from 6 to 8 feet high,‡ and about 1735, almost a century earlier, the Chickasaws met the attack of Bienville in a stockaded fort, and standing waist deep in a ditch.§ Going back still further, we are told by the Portuguese gentleman‖ that the wall around a town belonging to the Cacique of Coça, as well as that "of others which afterwards we saw, was of great posts thrust deep into the ground, and very rough; and many long rails, as big as one's arm, laid across between them, and the wall was about the height of a lance, and it was daubed within and without with clay, and had loopholes." The town of Mauvila was situated in a plain, and consisted of eighty houses, the smallest of which, according to La Vega, might contain six hundred persons. It was surrounded by a high rampart, palisaded with heavy beams of wood planted in the ground, and with timbers placed crosswise. The vacant places were filled in with earth mixed with straw, so that the wall looked like a piece of masonry. At every 50 paces there was a small tower with loopholes large enough to hold eight men The town had two gates and a large square in the middle, which was surrounded by the principal houses.¶ West of the Mississippi was the village of Capaha, which is said to have consisted of five hundred houses. It was situated on a little hill, surrounded by a ditch 10

* Martin, *North Carolina*, vol. I, p. 251: New Orleans, 1829.

† De Bry, plate XXX.

‡ Schoolcraft, *Indian Tribes*, vol. VI, p. 372.

§ *Hist. Coll. of Louisiana*, part II, p. 83: "Surrounded by timber 1 cubic foot placed circularly with three rows of loopholes; the Chicachas were bedded to the stomach in the earth," etc. "A large village, surrounded by a kind of wall made with potter's clay and sand, fortified with little towers at intervals, where we found fastened to a post the arms of Spain engraved on a copper plate, dated 1588." Cavelier in Shea's Early Voyages, p. 21, Albany, 1861. "The old village of the Akansea, where they formerly received the late Father Marquette, and which is discernible now only by the outworks (*dehors*), there being no cabins left." Father Gravier in *Shea's Early Voyages*, p. 126.

‖ *Hist. Coll. of Louisiana*, part II, p. 153.

¶ La Vega, seconde partie, p. 19.

or 12 cubits deep, and 50 paces wide in most places, and in others only 40. This ditch was kept full of water by means of a canal that had been dug from the town to the river Chucagua. The canal was 3 leagues long, a pike's length at least in depth, and so broad that two large boats could navigate it side by side. The fosse, filled by this canal, surrounds the city except in one place, which is closed by heavy posts planted in the ground, and fastened by means of others placed crosswise, the whole being covered with earth and straw. Within this town was the temple, in which were deposited the bones of the ancestors of the Capaha chief. This the Indian allies of De Soto pillaged, breaking open the coffins and scattering the bones. They also removed the heads of their countrymen, who had been killed in previous wars, and substituted those of the Capahas who had fallen in the recent battle.* This is the account left by Le Vega of this village, and though it is evidently exaggerated, as are all of his descriptions, yet there can be no doubt that it is substantially true, as it is confirmed in all important particulars by the other chroniclers of that expedition. Thus, for instance, Biedma † tells us that "they reached a village in the midst of a plain, surrounded by walls and a ditch which had been made by the Indians, filled with water;" and, according to the Knight of Elvas,‡ this town, which he calls Pacaha, "was very great, walled, and beset with towers, and many loop-holes were in the towers and wall. - - - Where the governor was lodged was a great lake that came near unto the wall; and it entered into a ditch that went round about the town, wanting but a little to environ it around. From the lake to the great river was made a wear by which the fish came into it. - - - With nets that were found in the town they took as much as they would; and took they never so much, there was no want perceived. Within a league and a half there were other great towns all walled."

Proceeding still farther to the northwest, we are told that, within the present century, the Mandans, Arikaras, and other tribes living high up on the Missouri, when they were first visited by the whites, were accustomed to fortify their towns by ditches, embankments, and palisades. Lewis and Clarke made repeated mention of recently abandoned Indian villages, surrounded by earthen walls, which in one case at least, are said to have been 8 or 10 feet high;§ and Brackenridge,|| who visited these same tribes in 1811, tells us of a citadel or fortification oval in form, and 4 or 5 acres in extent, around which a village had

* *Ibid.* Seconde partie, livre second, chap. vi and vii. Compare this with the account of the Temple of the Tensas, by Tonti, on p. 42.

† *Hist. Coll. of Louisiana*, part II, p. 105.

‡ *l. c.*, part II, p. 172.

§ Lewis and Clarke, vol. I, pp. 62, 92, 94, 97, 98, 108, etc.: Philadelphia, 1814. "The Omahas and Pawnees too, so I am told by Miss Alice C. Fletcher, formerly dug ditches around their villages, and made walls from 3 to 5 feet high."

|| *Views of Louisiana*, p. 242. He adds: "Probably, in case of siege, the whole village was crowded into this space."

apparently been built. The earthen wall that inclosed this fort was about 4 feet high, and upon it cedar posts were still standing. Struck with the resemblance, "in every respect," between these ruins and the "vestiges," as he calls the earth-works on the Ohio and the Mississippi, he very justly concluded that these latter were but the sites of stockaded towns and villages;* and this inference is borne out by the fact that on some of them "the remains of pallisadoes were found by the first settlers."†

That this resemblance is not altogether fanciful will be admitted by those who have followed the course of this investigation, though it is possible that the comparison would be more just if it were limited to the hill-forts of the Ohio Valley. Defensive works of the character of these latter seem to have been the same everywhere, and whether built by Iroquois, Chickasaw, Mandan, or Mound-builder, admit of no distinction in situation, form, or structure. Not so however with the class of works to which the term fortified village has been applied. These are groups rather than single works, and though primarily nothing but mounds, ditches, and embankments, and as such differing in nowise, except perhaps in size, from similar structures elsewhere, yet they are often arranged in such a complicated manner as to have but little in common with the inclosures, north of the Ohio, that are known to have been erected by the modern Indians. For their counterparts we must look to the Gulf States, Georgia and Arkansas, and it is possible that, even here, they will be found to be neither so large nor so complicated. Upon this point however it is necessary to "make haste slowly," as our knowledge of the earth-works in the Southern States is very slight; and there can be no doubt that the statement of the Portuguese Gentleman‡ as to the existence of "great and walled towns, and many houses scattered all about the fields, to wit: a cross-bow shot or two, the one from the other," taken in connection with what is known of the manner in which these tribes built their houses and fortified their villages, is suggestive of a condition of affairs strongly resembling the famous mound centers of the Ohio Valley.§ In all other respects,

* *Ibid.*, p. 183. Compare Catlin, vol. II, pp. 259 *et. seq.*

† *Ibid.*, p. 21.

‡ *l. c.*, pp. 160, 169, 170, 144, and 172. The Indians everywhere throughout this region built their villages in groups, some of which were very large. Upon this point consult the other chroniclers of De Soto's expedition and the narratives of Father Douay, p. 204, and Gravier, pp. 133, 138, and 148; also Adair, p. 352, and Charlevoix, *Letters* ii, p. 245 *et seq.*: London, 1761.

§ A series of explorations, under the auspices of the Peabody Museum of American Archæology and Ethnology, has recently been conducted amid the mounds and village sites of the northeastern portion of Arkansas—the region that the Capahas are supposed to have inhabited in the time of De Soto, and where they were found by Fathers Douay and Charlevoix in 1687 and 1721—and it is curious to note how the statement of the old chronicler as to the existence of "walled towns within a league or a league and a half of each other" is verified. See *Fourteenth Annual Report of the Peabody Museum*, p. 19, where we are told that "these mounds are usually sur-

the works of the Southern Indians, such as they have been described by the early chroniclers, will compare favorably with anything of the same character that has yet been found in the United States. The truncated or temple mounds are far more numerous in the States south of the Ohio than anywhere else in the Mississippi Valley, and except in one or two notable instances, are of larger size; whilst the artificial ponds, with canals to feed them, are believed to be peculiar to that region.

Of the other earth-works—the stone cairns, burial mounds, graded ways, ditches, and embankments—it can only be said that they are common to both sections, and that the only difference between them is in their size, or in the order in which they are sometimes grouped together. Even in these particulars the advantage is not always on one side, for the reason that there is no uniformity in any of the works, and whilst, as a matter of fact, the largest and most complicated group of the Ohio system exceeds anything that has yet been found in the Gulf States, it is equally true that there are mounds and embankments south of the Ohio that are larger than are many of those found to the north of that stream. Between the giant mass of the Cahokia, Ill., mound and the long lines of embankment on Paint Creek, Ohio, and their counterparts in Mississippi* and elsewhere in the Southern States,† the difference is much less than it is between these same works and the average of those of similar character in the northern half of the Ohio Valley. But even if there were no such differences, and the groups in the Ohio system of works were uniformly of larger size and more complicated pattern than can be found elsewhere in the United States, the fact would still be without any ethnical significance; otherwise we should have to admit that there existed in the Ohio Valley at or about the same time, and in close proximity to each other, as many different races or phases of civilization as there are groups of works, and this would be absurd.

With the establishment of this point, my task is brought to a close. In it I have confined myself almost entirely to the historical proof of the recent origin of these works, and except incidentally, have ignored the argument that may be drawn from the similarity of burial customs, and from the identity of the implements and ornaments found in the

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rounded by earthworks and ditches, forming inclosures of from 3 or 4 to 18 or 20 acres;" and the MS. field notes of the late Mr. Edwin Curtiss, now in the Peabody Museum, for the relative situation of some of these inclosures.

* The great mound at Seltzertown, Miss., according to Brackenridge, Appendix to *Views of Louisiana*, was a truncated pyramid 600 by 400 feet, and 40 feet in perpendicular height. It was ascended by graded ways, and the area on top embraced about 4 acres. At each end of this area, and near the center, were other mounds, one of which was about 40 feet high, with a level space at its summit 30 feet in diameter. The whole was surrounded by a ditch that averaged 10 feet deep.

† For the size of some of these works, see *ante*, foot-note † on page 585. Compare also Squier, *Aborig. Mon. of the Miss. Valley*, pp. 113 *et seq.*, and Jones, *Antiquities of the Southern Indians*, p. 163, New York, 1873.

mounds with those that are known to have been made and used by the recent Indians. This has not proceeded from any failure to appreciate the full ethnical significance of these resemblances, nor has it been caused by any lack of material; but it has been the result of the limits voluntarily placed upon the investigation. At some future time it may be necessary to revert to this subject, and then it will be competent to show that the "vestiges of art" found in the mounds "do not excel in any respect those of the Indian tribes known to history."* In the meantime we can well afford to content ourselves with this brief and cursory examination into the early records. Summing up the results that have been attained, it may be safely said, that so far from there being any *a priori* reason why the red Indians could not have erected these works, the evidence shows conclusively that in New York and the Gulf States they did build mounds and embankments that are essentially of the same character as those found in Ohio. And not only is this true, but it has also been shown that whilst for reasons that have been given, we are without any historical account of the origin of the Ohio system of works—the only one about which there seems to be any dispute—yet there can be no doubt that one of the more elaborate of them, viz: the mound at Circleville, in which were found articles of iron and silver, was built after contact with the whites, and therefore by the recent Indians.

In view of these results, and of the additional fact that these same Indians are the only people, except the whites, who, so far as we know, have ever held the region over which these works are scattered, it is believed that we are fully justified in abandoning the seemingly negative position occupied at the outset of this argument, and in claiming that the mounds and inclosures of Ohio, like those in New York and the Gulf States, were the work of the red Indians of historic times, or of their immediate ancestors. To deny this conclusion, and to accept its alternative, ascribing these remains to a mythical people of a different civilization, is to reject a simple and satisfactory explanation of a fact in favor of one that is far-fetched and incomplete; and this is neither science nor logic.

*J. W. Powell, in *Transactions of the Anthropological Society of Washington*, p. 116: Pamphlet, 1881.

# THE USE OF FLINT BLADES TO WORK PINE WOOD.*
## (EPOCH OF THE ANCIENT SHELL HEAPS.)

By G. V. Smith.

In the discussions which have been going on for more than thirty years concerning the division of the Stone age in Denmark into two periods, that of the shell heaps, and that of the megalithic monuments, one of the principal objections made to the theory of Worsaae has always been that the blades simply chipped could not be employed as axes, and ought, upon the whole, to be taken out of the list of cutting instruments.†

These implements have however when they are in good condition, a sharp border, analogous to an edge, which has always been produced by the same process, that is to say, by striking off a single chip from each side of a flint disc so as to form an edge by the line of intersection of the two faces, whose angle of inclination is not ordinarily larger than the corresponding angle of the cutting part of the polished axes. But objection has been made that this sharp border is not suitable for an edge, consequently the implement could not be employed as an ax.

If we examine with care the great series of chipped blades which are found in such abundance in the National Museum of Copenhagen, as well as in other Danish collections, we find out however that in all the examples in good condition, the cutting part is precisely like an edge, whether we regard the form or the idea of a cutting tool, also from this point of view it does not seem rational that this kind of edge would have been merely accessory in the chipped blades and that they did not have any importance in the eyes of those who made use of these implements. It is then difficult to understand why there is any hesitation in considering them to have been cutting implements, especially when it is possible to show the successive development of the forms, from the largest blades to the most complete

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*From Aarbøger fer nordisk Oldkyndighed og Historie, 1891, 2 ser., VI, fasc. 4, pp. 383-396, and rendered into French by E. Beauvois, in *Mem. d. l. Soc. Roy. d. Antiq. du Nord.* Copenhagen, n. s. 1891, pp. 99-110.

† *Mem. d. l. Soc. d. Antiq. du Nord.* 1884-'89, 371.

types of edged instruments made in the usual manner for blades and approaching more and more the published flint axes.

Blades with a perfect edge are rare, naturally; for it was not worth the trouble to recut them, and those were thrown away which could not be used. The edge produced by simply striking off two fragments of flint, without doubt, had not the resistance of an edge made by polishing; but as the ancients did not experience any difficulty in making new blades, the frailty of the edge would not be of any great importance, as they had flint in abundance. It is this which naturally explains the great quantity of blades more or less damaged, which are found, not only on the Danish borders and in the shell heaps, but anywhere in the interior of the country.

The question of the use of these blades as cutting instruments has already been fully treated, especially by Dr. Sophus Müller.* I will not go into details. The theoretical part of the subject has also been exhausted. It only remains to prove by practical experiments how far the blades, when furnished with handles, can cut wood.

The success of these experiments ought to be a strong argument in favor of those who hold that flint blades of the ancient shell-heap epoch have been used in the same manner as polished tools from the last period of the Stone age, that is to say, as cutting or chopping instruments, and as weapons. I have undertaken these experiments, and give here the results. The co-operation of an able assistant was indispensable to me. So I called in the aid of a master carpenter of Aarhus, M. Helstrup, who has shown great interest and aptitude in the subject in assisting me in the practical part of the work.

The blades used have been hafted partly in imitation of the stone axes which are to be found in the National Museum of Copenhagen (Department of Ethnology), and partly after the cuts in works on Archæology.† In trying the different kinds of mountings, it was decided that the most advantageous form is one copied from works on the construction of pile dwellings of the Swiss Lakes, I made a maple handle 7 centimeters ($2\frac{3}{4}$ inches) in diameter, and about 58 centimeters (23 inches) in length, preserving this thickness about 12 centimeters ($4\frac{3}{4}$ inches) from the end, and then tapering it slightly to the other end.

As the blades placed at my disposal for the experiment were relatively small, I could not fasten them directly into the handle; the edge would have been so near the handle that it would have made the work difficult, especially in cutting down trees, where it would have been necessary to strike at an open angle; besides, in a handle of this kind it was difficult to give stability to the stone blade. The blades would be

* "Classification of the antiquities of Denmark, Copenhagen," 1888. *Mem. d. l. Soc. d. Antiq. du Nord.*, 1884–'89, p. 731. *Aarb. f. Nord., Oldkyndighed*, etc., 1888, 1890.

† J. Evans: *Ancient Stone Implements of Great Britain.* F. Sehested: *Fortidsminder og Oldsager fra Egnen om Broholm, et Archæologiske Underlogelser*, 1878–1881. Keller: Pfahlbauten, *Mittheil, d. Antiquar, Gesellsch in Zürich.*

mounted more advantageously in an intermediate piece, like those which were generally made for the axes of stone in handles found in the Swiss lake cities. First of all, by that means, it became possible to fix them immovably in the helve; and secondly, which was most essential, to place between the edge and the handle the distance appropriate for the use of the implement. The intermediate pieces which I used were of elm or beech 0.12 to 0.13 meter (4¾ to 5 inches) long, 0.4 to 0.5 meter (16 to 20 inches) wide, and 0.3 to 0.4 meter thick. These were split at one end to insert the blade, and the interstices were filled with a kind of pitch used by saddlers. After having wrapped with a piece of leather the two sides of the blade which protruded beyond the cleft, this was tightly bound with cord. The other end of the intermediate piece was rounded and slightly pointed so as to be more easily introduced into the corresponding hole in the handle. This hole was bored obliquely in the middle of the thickest part of the handle, in such a way that the blade formed an obtuse angle with the upper extremity of the handle. This arrangement was found to be necessary, for otherwise it would not have been the middle of the edge which struck the tree but the outer corner; that is to say, the one farthest from the hand. This point would have soon been probably broken, which would not be the case when the edge was properly set in an oblique position. This solid hafting was like those used in Denmark in primitive times, and the dowel of wood in which is set a blade found in the fiords of Kolding and represented on page 392 of the memoir of S. Müller, served as an intermediate piece.

With these blades thus hafted I have executed the works here described on green pine, not that the kind of wood plays an important part in these experiments, for it is to be supposed that blades cutting one kind will do as much on all other kinds of the same hardness; but as most of the forests of Denmark during the stone age consisted nearly exclusively of pines, as Prof. Steenstrup has demonstrated, I have made my investigations on the Pinus silvestris of different sizes cut down in the woods of Frijsenborg in the beginning of January, and I have continued them from the 27th to the 31st of the same month.

I. A stick of pine wood 0.0555 meter in diameter, which was fixed perpendicularly on a work-bench, was cut in two in three-quarters of a minute; it did not break off until it had been reduced to 0.007 meter in diameter; the severed piece was sharpened like a pile.

II. Another stick, 0.1225 meter in diameter, placed in the same position was cut in ten minutes. It was broken off by force when it was not more than 0.02 meter in diameter.

III. A stick placed in the same position was cut in eighteen minutes; it broke off when it was 0.05 meter. It was necessary to strike 1,578 blows to do the work. At the 1,485th strike a little fragment separated itself from the edge. Even at the beginning the edge struck accidentally

on a piece of iron which made it bound, and caused a small fragment 0.03 meter long and 0.003 meter thick to fly off one of the corners without diminishing the sharpness of the axe.

These three experiments were made with the same blade, 0.075 meter long, of gray flint, of which the edge, a little concave, was 0.065 meter in width. At one of the corners of this some chips were wanting, having been broken off before the experiment. It was otherwise in a good condition, and very sharp, only having serrations here and there. The shorter of the beveled faces is a little curved and this made the blade slightly convex. The scarfs produced by the cutting were perfectly regular and exact, and the surface, left by the removal of the chips would have been also quite smooth if the serrations of the edge had not left some inequalities.

IV. In striking some blows on a pine pole, dry and not planed, 0.03 meter thickness, I have proved that the same blade would quite as well cut harder wood.

It would have been naturally much easier to fell a sapling standing than to cut the blocks fixed on a stand, for the wood yielded in a manner to compress the fibers in one way and expand them in the other; the blows penetrated better in the latter case.

V. A log of pine 0.13 meter in diameter, fixed on a table, was cut in eight minutes with the ax. It is a blade of gray flint 0.07 meter long, of which the convex and uneven edge is 0.0675 meter wide. Before the experiment the edge was a little damaged in the middle and did not work as well. The chips were short and the incisions uneven. The part separated from the log which was pointed with the ax used in the first three experiments, shows the surfaces equal and nearly polished.

VI. One of the logs had the knots which I had succeeded in avoiding in the preceding experiments. With a blade whose edge was extraordinarily straight and regular, but a little thick (the bevelled parts show an angle of inclination of 45°), I cut with the greatest ease these knots, of which the largest was 0.03 meter in diameter, without any marks thereof appearing on the edge. The thickness of this ax, on the contrary, makes it cut with less facility into wood soft and without knots. To ascertain the limits of resistance in this blade, I struck with all my force, almost perpendicularly, a large knot remaining on a branch cut on the stump. The branch was standing horizontally. The edge penetrated in the knot 0.01 meter, but the same time the ax split, and the thick fragment broke off about a third of the edge and all the narrow face of the ax, which came off from the head.

VII. The experiment showed to me that the little blades could perfectly take the place of chisels.

VIII. With the same instruments used as chisels I shaped two logs to mortise and tenon. All the logs of the experiment were still covered with bark.

These experiments clearly showed me with what astonishing easiness and relative rapidity the pine could be felled with these blades. With the primitive implements one is able, not only to cut large trees, but to perform the work of less complicated carpentry, without the cutting edge becoming very readily deteriorated. If one considers, in addition, that the carpenters of antiquity were particularly skillful and clever in the use of blades, one can with reason now consider that these were used as "edged tools," and the experiments here described have convinced me that the large blades were employed as axes.

## MODES OF KEEPING TIME KNOWN AMONG THE CHINESE.

* BY D. J. MAGOWAN, M. D.

According to the Shu-king, we find that forty-five centuries ago the Chinese had occupied themselves with the construction of astronomical instruments analogous to the quadrant and armillary sphere; the observations they made with them, even at that remote period, are remarkable for their accuracy, enabling them to form a useful calendar. The present sexagenary cycle was adopted B. C. 2636, by Hwangti, to whom is attributed the invention of the clepsydra. The instrument at that period was probably very rude, used principally for astronomical purposes in the same manner as employed by Tycho Brahe for measuring the motion of stars, and subsequently by Dudelz in making maritime observations. It was committed to the care of an officer styled the *clepsydra adjuster*.

Duke Chan, the alleged inventor of the compass, about B. C. 1130, appears also to have been the first to employ the clepsydra as a timepiece. He divided the floating index into one hundred *kih*, or parts. In winter forty *kih* were allotted for the day and sixty for the night; in summer this was reversed, the spring and autum being equally divided. This instrument was provided with forty-eight indices, two for each of the twenty-four *tsieh*, or terms of the year. They were consequently changed semi-monthly, one index being employed for the day and another for the night. Two were employed every day, probably to remedy in a measure the defect of all clepsydras, *i. e.*, of varying in the speed of their rise and fall, according to the ever-varying quantity of water in the vessel, which might be done by having the indices differently divided. To keep the water from freezing, the instrument was connected with a furnace, and surrounded with hot water. The forms of the apparatus have been various, but they generally consisted of an upper and a lower copper vessel, the former having an aperture in the bottom through which water percolated into the latter, where floated an index, the gradual rise of which indicated successive periods of time.

* From *Chinese Repository*, July, 1851.

In some this was reversed, the float being made to mark time by its fall. A portable one was sometimes employed in ancient times on horseback.

Instruments constructed on the same principles were in use amongst the Chaldeans and Egyptians at an early period; that of Ctesibius of Alexandria being an improvement over those of more ancient times. The invention in Western Asia was doubtless independent of that in Eastern, both being the result of similar wants. Clepsydras were subsequently formed of a succession of vessels communicating by tubes passing through figures of dragons and other images, which were rendered still more ornamental by the indices being held in the hands of genii. The earliest application of motion to the clepsydra appears to have been in the reign of Shunti A. D. 126–145, by Tsiang-hung, who constructed a sort of orrery representing the apparent motion of the heavenly bodies around the earth, which was kept in motion by dropping water. There is also a reference to an instrument of this description in the third century.

In the sixth century an instrument was in use which indicated the course of time by the weight of water, as it gradually came from the beak of a bird, and was received in a vessel on a balance, every pound representing a *kih*. About this time mercury began to be employed in clepsydras instead of water, which rendered the aid of heat in winter unnecessary. Changes were made also in the relative number of *kih* for day and night, so as to vary with the seasons as in Europe. Monks of the Romish Church devoted considerable attention to the construction of instruments for measuring time; in like manner also, Budhist monks in their silent retreats, but at an earlier period, similarly occupied themselves. Several contrivances to measure time are mentioned in Chinese history as the invention of priests. One was a perforated copper vessel, placed in a tub of water, which gradually filled and sunk every hour; such a rude machine required of course constant attention.

Although their knowledge of hydro-dynamics is limited, the Chinese appear to have been the first to invent the form of clepsydra to which the term *water clock* is alone properly applied—that is to say, an apparatus which rendered watching unnecessary by striking the hours. Until the beginning of the eighth century the persons employed to watch the clepsydra in palaces and public places struck bells or drums at every *kih*, but at this period a clock was constructed, consisting of four vessels, with machinery which caused a drum to be struck by day and a bell by night, to indicate the hours and watches. No description of the works of this interesting invention can be found. It is possible however that the Saracens may have anticipated the Chinese in the invention of water clocks. In the History of the Tang Dynasty it is stated that in the Fuhlin country (which in this instance doubtless means Persia, though the geographer Sii makes it Judea), there is a clepsydra on a terrace near the palace formed of a balance which contained twelve metallic balls, one of which fell every hour on a bell, and

thus struck the hours correctly. It is not improbable that this instrument is identical with the celebrated one which the King of Persia sent in the year 807 to Charlemagne.

In 980 an astronomer named Tsiang made an improvement on all former instruments, and considering the period it was a remarkable specimen of art. The machine was arranged in a sort of minature terrace, ten feet high, and was divided into three stories, the works being in the middle. Twelve images of men, one for every hour, appeared in turn before an opening in the terrace. Another set of automata struck the twelve hours and the eighths of such hours. These figures occupied the lower story. The upper story was devoted to astronomy, where there was an orrery in motion, which it is obvious must have rendered very complex machinery necessary. We are only told that it had oblique, perpendicular, and horizontal wheels, and that it was kept in motion by falling water. As the Arabs had reached China by sea at the close of the eighth century, and by land at an earlier period, some assistance may have been derived from them in the construction of this instrument, but I am disposed to consider it wholly Chinese. Beckmann, after much learned research, ascribes the invention of clocks to the Saracens, and the first appearance of their instruments in Europe to the eleventh century.

Mention may here be made of other time-keeping instruments of the same description, also constructed about this period. One, which like the last united an orrery and clepsydra, was formed in one part like a water lily, whilst in another were images of a dragon, a tiger, a bird, and a tortoise, which struck the *kih* on a drum, and a dozen puppets which struck hours on a bell, with various other motions, besides a representation of the revolutions of the heavenly bodies. The machinery of another of these was moved by an undershot waterwheel, its axis was even with the surface of the ground, and consequently the frame containing it was partly below the surface. The motions of the sun and moon, stars and planets, were made to revolve from east to west around a figure of the earth, represented as a plain. Images of men struck the hour and its parts. In this, as in all the above-named instruments, the number of strokes was doubtless always the same, as Chinese do not count but name the hours.

Another machine was contrived which also represented the motion of the heavenly bodies. It was a huge hollow globe, perforated on its surface so as to afford, when lighted up, a good representation of the sky in the dark. This also was set in motion by falling water. Subsequent to this various machines are mentioned, but the brief notices given afford nothing of interest until we approach the close of the Yuen dynasty. Shun-tsing (A. D. 1330–'60), the last emperor of the Mongol race, described in history as an effeminate prince with the physiognomy of a monkey, was evidently a man of great mechanical skill, and to the last amused himself by making models of vessels,

automata, and timepieces. His chief work was a machine contained in a box 7 feet high and 3½ wide, with three small temples on top. The middle of these temples had fairies holding horary characters, one of which made her appearance every hour. Time was struck by a couple of gods, and it is said they kept it very accurately. In the side temples were representations of the sun and moon respectively, and from these places genii issued, crossing a bridge to the middle temple, and after ascertaining, as it were, the time of day from the fairies, returning again to their quarters. It is thought the motions were in this case effected by springs. An instrument somewhat similar is described as being in the capital at Corea; it was a clepsydra, with springs representing the motions of the celestial orbs, and having automata to strike the hour. Since the introduction of European clocks, clepsydras have fallen into disuse. The only one perhaps in the empire is that in a watchtower in the city of Canton.* It is of the simplest form, having

* This clepsydra is found on top of a gateway called Shwang-mun ti, standing in the street called Hinng chin fang, leading north from the great South Gate to the Puching sz' office. This street, or avenue, is more than 50 feet wide, and this double gateway crosses the street in its widest part like Temple Bar in London, each passage being about 20 feet across. The structure is very strongly built, and is ascended by stone steps on the outside; on the top is a two-storied red loft, called Kung-peh lan, the upper story of which serves as a repository for the blocks used in the printing office in the lower story From this printing office are issued statistical and other official works, under the direction of the Puching sz'. In the middle wall is a vault, and the ground sounds hollow underneath. The statistics of Kwang chau fu (Canton) gives the following notices of the edifice: "The Kung-peh lan lies south of the Puching sz' office, and was called the Tsinghai lan in the Tang dynasty; it stood between two hills, which Sin Hien levelled, and there erected a double stone gateway. The General Sz'ma Kih in A. D. 1100, re-built it, and called it the Double Gateway; it was destroyed about 1350, and re-built as before by Hungwu in 1380, and again repaired in 1654 by Shunchi, and by Kanghi in 1687. On the top is a clepsydra, which the officer Chin Yungho made in 1315, during the reign of Jintsung."

The clepsydra is called the *tung-wu-tih-lau, i. e.,* copper jar dropper, and is placed in a separate room, under the supervision of a man who, besides his stipend and perquisites, obtains a livelihood by selling time-sticks. There are four covered copper jars standing on a brickwork stairway, the top of each of which is level with the bottom of the one above it; the largest measures 23 inches high and broad, and contains 70 catties, or 97½ pints of water; the second is 22 inches high and 21 inches broad; the third is 21 inches high, and 20 inches broad; and the lowest 23 inches high and 19 inches broad. Each is connected with the other by an open trough, along which the water trickles. The wooden index in the lowest jar is set every morning and afternoon at 5 o'clock, by placing the mark on it for these hours even with the cover, through which it rises and indicates the time. The water is dipped out and poured back into the top jar when the index shows the completion of the half day; and the water is renewed every quarter. Two large drums stand in the room, on which the watchmen strike the watches during the night. Probably a ruder contrivance to divide time can hardly be found the world over, and if it was not for the clocks and watches everywhere in use, which easily rectify its inaccuracies, the Cantonese would soon be greatly behindhand in their reckoning, so far as they had to depend on this clepsydra and the time-sticks which are burnt to regulate it.—*Editor Chinese Repository* (July, 1851).

no movements of any kind, but it is said to keep accurate time. The Chinese automata so much admired, are in their internal structure imitations of foreign articles.

In dialling the Chinese have never accomplished anything, being deficient in the requisite knowledge of astronomy and mathematics. It is true the projection of the shadow of the gnomon was carefully observed at an early historic period for astronomical purposes. Proper sun-dials were unquestionably derived from the West; but they were not introduced, as Sir John Davis supposes, by the Jesuits. The Chinese are probably indebted to the Mohammedans for this instrument, although we find an astronomer endeavoring to rectify the clepsydra by means of the sun's shadow, projected by a gnomon, about a century earlier than the Hejira. There is one in the Imperial Observatory at Peking more than 4 feet in diameter. Smaller ones are sometimes met with in public offices, all made under the direction of Romish missionaries or their pupils.

From remote antiquity a family named Wang, residing in Hiu-ning-hien (latitude 29° 53′ N., longitude 118° 17′ E.) in the province of Nganhwui, has had the exclusive manufacture of pocket compasses, with which sun-dials are often connected. In most of these a thread attached to the lid of the instrument serves as a gnomon without any adaptation for different latitudes, although they are in use in every part of the empire. Another form, rather less rude, used by clock-makers for adjusting their timepieces, is marked with notches, one for each month of the year, to give the gnomon a different angle every month. The one used by the Japanese exceeds that made in China in every respect.

Time is often kept with tolerable accuracy in shops and temples by burning incense sticks made of sawdust, carefully, but slightly, mixed with glue, and evenly rolled into cylinders two feet long, and divided off into hours. When lighted, they gradually consume away without flame, burning up in half a day. Hour-glasses are scarcely known in China, and only mentioned in dictionaries as instruments employed in western countries to measure time. A native writer on antiquities says the western priest, li Ma-tau (M. Ricci), made a clock which revolved and struck time a whole year without error. The clock brought out by Ricci, if not the first seen in China, is the earliest of which mention is made in Chinese history. This subsequently became an article of import, and this branch of trade has for a long time been, and is still, of considerable value. Clocks and watches of very antique appearance are often met with, specimens of the original models scarcely to be found in any other country. Some of the latter, by their clumsy figure, remind one of their ancient name, "Nuremburg eggs," but their workmanship must have been superior to that of most modern ones, or they would not be found in operation at this late day.

The Chinese must have commenced clock-making at an early period, for no one now engaged in the trade can tell me when or where it originated, nor can it be easily ascertained whether their imitative powers alone enabled them to engage in such a craft, or whether they are indebted to the Jesuits for what skill they possess. It is certain that the disciples of Loyola had for a long time, and until quite recently in their corps at Peking, some who were machinists and watch-makers One of these *horologists* complains in *Les Lettres Edifiantes* that his. time was so much occupied with mending the watches of the grandees that he had never been able to study the language. Doubtless the fashion which Chinese gentlemen have of carrying a couple of watches, which they are anxious should always harmonize, gave the man constant employment. A retired statesman of this province has published a very good account of clocks and watches, accompanied with drawings representing their internal structure in a manner sufficiently intelligible. The Chinese divide the whole day into twelve parts, which are not numbered, but each one is designated by a character, termed *horary*. These characters were originally employed in forming the nomenclature of the sexagenary cycle, which is still in common use. It was not until a much later period that the duodecimal division of the civil day came into use, when terms to express them were borrowed from the ancient calendar. The same characters are also applied to the months. The first in the list, *tsz'* son, is employed at the commencement of every cycle, and to the first of every period of twelve years, and also to the commencement of the civil day, at 11 P. M., comprising the period between this and 1 A. M. The month which is designated by this term is not the first of the Chinese year, and singularly enough coincides with January. Each of the twelve hours is divided into *kih*, answering to a quarter of an hour. This diurnal division of time does not appear to have been in use in the time of Confucius, as mention is made in the spring and autumn annals of the ten hours of the day, which accords with the decimal divisions so long employed in clepsydras, the indices of which were uniformly divided into one hundred parts. A commentator in the third century of our era, explaining the passage relating to the ten hours, adds a couple of hours, but even at that time the present horary characters were not employed.

# NAVAJO DYE STUFFS.*

By Dr. Washington Matthews, U. S. Army.

The art of weaving among the Navajo Indians of New Mexico and Arizona is of aboriginal origin. They probably learned the art from the ancient Pueblo Indians. No native tribe has carried it to such perfection nor in any has European influence had less effect.

*Material for fabrics.*—Cotton which grows well in New Mexico and Arizona, the tough fibers of yucca leaves and the fibers of other plants, the hair of different quadrupeds, and the down of birds furnished in prehistoric days the materials of textile fabrics in this country. While some of the Pueblos still weave their native cotton to a slight extent, the Navajos grow no cotton and spin nothing but the wool of the domestic sheep, of Spanish introduction, and of which the Navajos have vast herds. The wool is not washed until it is sheared. It is combed with hand combs purchased from the Americans. In spinning, the simplest form of the spindle, a slender stick thrust through the center of a round wooden disk, is used. The Mexicans on the Rio Grande use spinning wheels, and although the Navajos have some of their own, and have abundant opportunities for buying or stealing them, and possess, I think, sufficient ingenuity to make them, they have never abandoned the rude implement of their ancestors. The Navajo method of handling the spindle is different from that of the people of Zuñi.

The Navajos still employ, to a great extent, their native dyes; of yellow, reddish, and black. There is good evidence that they formerly had a blue dye; but indigo, originally introduced, I think, by the Mexicans, has superseded this.

Specimen No. 1, Catalogue No. 153348, is wool dyed blue with indigo, the mordant being urine. If they in former days had a native blue and a native yellow, they must also, of course, have had a green, and they now make green of their native yellow and indigo, the latter being the only imported dye-stuff I have ever seen in use among them. Besides the hues above indicated, the people have had, ever since the introduction of sheep, wool of three natural colors—white, rusty black,

* "Navajo Weavers:" *Third Annual Report, Bureau of Ethnology*, 1881–'82, p. 375.

and gray—so they have always a fair range of tints with which to execute their artistic designs. The brilliant red figures in their finer blankets were, a few years ago, made entirely of *bayeta*, and this material is still largely used. Bayeta is a bright, scarlet cloth, with a long nap, much finer in appearance than the scarlet stronding which forms such an important article in the Indian trade of the North. It was originally brought to the Navajo country from Mexico, but is now supplied to the trade from our eastern cities. The Indians ravel it and use the weft. While many handsome blankets are still made only of the colors and material above described, American yarn has lately become very popular among the Navajos, and many fine blankets are now made wholly, or in part, of Germantown wool.

*Yellow.*—There are, the Indians tell me, three different processes for dyeing yellow; two of these I witnessed. The first process is thus conducted. (Specimen No. 2, Catalogue No. 153349, is wool dyed by this process.)

The flowering tops of *Bigelovia graveolens* are boiled for about six hours, until a decoction of deep-yellow color is produced. When the dyer thinks the decoction is strong enough, she heats over the fire in a pan or earthen vessel some native almogen (an impure native alum), until it is reduced to a somewhat pasty consistency; this she adds gradually to the decoction, and then puts the wool in the dye to boil. From time to time a portion of the wool is taken out and inspected until (in about half an hour from the time it is first immersed) it is seen to have assumed the proper color. The work is then done. The tint produced is nearly that of lemon color. (No. 2.)

In the second process they use the large fleshy root of a plant which, as I have never yet seen it in fruit or flower, I am unable to determine. The fresh root is crushed to a soft paste on the *metate*, and, for a mordant, the almogen is added while the grinding is going on. The cold paste is then rubbed between the hands into the wool. If the wool does not seem to take the color readily a little water is dashed on the mixture of wool and paste, and the whole is very slightly warmed. The entire process does not occupy over an hour, and the result is a color much like that now known as "old gold."

The dull reddish dye, specimen No. 3, Catalogue No. 153350, is made of the bark of the Alder, *Alnus incana* var. *virescens* (Watson) and the bark of the *Cercocarpus parvifolius*, a kind of mountain mahogany. On buckskin this makes a brilliant tan color, but applied to wool it produces a much paler shade, as shown in the specimen (No. 3).

The orange dye, Specimen No. 4, Catalogue No. 153351, is made from the roots of a sorrel *Rumex hymenosepalum*.

Specimen No. 5, Catalogue No. 153352, is wool, half natural white and half dyed black, carded together.

*Black dye.*—The black dye, specimen No. 6, Catalogue No. 153353, is made of the twigs and leaves of the aromatic sumac (*Rhus aromatica*).

a native yellow ocher, Specimen No. 7, Catalogue No. 153354, and the gum of the pinon (*Pinus edulis*), Specimen No. 8, Catalogue No. 153355. The process of preparing it is as follows: They put into a pot of water some of the leaves of the sumac, and as many of the branchlets as can be crowded in without much breaking or crushing, and the water is allowed to boil for five or six hours until a strong decoction is made. While the water is boiling they attend to other parts of the process. The ocher is reduced to a fine powder between two stones and then slowly roasted over the fire in an earthen or metal vessel until it assumes a light-brown color; it is then taken from the fire and combined with about an equal quantity in size of pinon gum; again the mixture is put on the fire and constantly stirred. At first the gum melts and the whole mass assumes a mushy consistency; but as the roasting progresses it gradually becomes dryer and darker until it is at last reduced to a fine black powder. This is removed from the fire, and when it has cooled somewhat it is thrown into the decoction of sumac, with which it instantly forms a rich, blue-black fluid. This dye is essentially an ink, the tannic acid of the sumac combining with the sesquioxide of iron in the roasted ocher, the whole enriched by the carbon of the calcined gum.

The effect and color of the dyes are shown in the accompanying specimens on wool of the Navajo sheep.

No. 1. Cat. No. 153348. Blue—dyed with indigo.

No. 2. Cat. No. 153349. Yellow—a decoction of the flowering tips of *Bigelovia graveolens*, mixed with almogen (a native impure alum).

No. 3. Cat. No. 153350. Dull red—dyed with bark of Alder, *Almus incana*, var *Viresceno* (Watson), and bark of *Cercocarpus parvifolius*, a kind of mountain mahogany; the mordant, fine ashes of the juniper.

No. 4. Cat. No. 153351. Orange—dyed with roots of a sorrel—*Rumex hymenosepolum.*

No. 5. Cat. No. 153352. Wool—half natural white and half dyed black, carded together.

No. 6. Cat. No. 153353. Black dye—made of a decoction of the twigs and leaves of aromatic sumac, *Rhus aromatica*, yellow ocher and gum of pinon, *Pinus edulis.*

No. 7. Cat. No. 153354. Native ocher—for making the black dye.

No. 8. Cat. No. 153355. Powder of yellow ocher and pinon gum, calcined together—for making black dye.

# SOME OF THE POSSIBILITIES OF ECONOMIC BOTANY.*

By George Lincoln Goodale.

The subject which I have selected for the valedictory address deals with certain industrial, commercial, and economic questions: nevertheless its lies wholly within the domain of botany. I invite you to examine with me some of the possibilities of economic botany.

Of course, when treating a topic which is so largely speculative as this, it is difficult and unwise to draw a hard and fast line between possibilities and probabilities. Nowadays possibilities are so often realized rapidly that they become accomplished facts before we are aware.

In asking what are the possibilities that other plants than those we now use may be utilized we enter upon a many-sided inquiry.† Speculation is rife as to the coming man. May we not ask what plants the coming man will use?

There is an enormous disproportion between the total number of species of plants known to botanical science and the number of those which are employed by man.

The species of flowering plants already described and named are about 107,000. Acquisitions from unexplored or imperfectly explored regions may increase the aggregate perhaps one-tenth, so that we are within

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* Presidential address delivered before the American Association for the Advancement of Science, at Washington, August, 1891, from the *Proceedings Am. Assoc. Adv. Sci.*, 1891, vol. XL, pp. 1–38; also, *the American Journal of Science*, October, 1891, vol. XLII, pp. 273–303.

† The following are among the more useful works of a general character, dealing with the subject. Others are referred to either in the text or notes. The reader may consult also the list of works on Economic Botany in the catalogue published by the Linnæan Society:

*Select Extra-tropical Plants*, readily eligible for industrial culture or naturalization, with indications of their native countries and some of their uses. By Baron Fred. von Mueller, K. C. M. G., F. R. S., etc., Government Botanist for Victoria. (Melbourne), 1888. Seventh edition, revised and enlarged. At the close of his treatise on industrial plants, Baron von Mueller has grouped the genera indicating the different classes of useful products in such a manner that we can ascertain the respective numbers belonging to the genera. Of course many of these genera figure

very safe limits in taking the number of existing species to be somewhat above 110,000.*

Now if we should make a comprehensive list of all the flowering plants which are cultivated on what we may call a fairly large scale at the present day, placing therein all food† and forage plants, all those which are grown for timber and cabinet woods, for fibers and cordage, for tanning materials, dyes, resins, rubber, gums, oils, perfumes, and medicines, we could bring together barely 300 species. If we should add to this short catalogue all the species which without cultivation can be used by man, we should find it considerably lengthened. A great many products of the classes just referred to are derived in commerce from wild plants, but exactly how much their addition would extend the list it is impossible, in the present state of knowledge, to determine. Every enumeration of this character is likely to contain errors from two sources: First, it would be sure to contain some species which have outlived their real usefulness; and, secondly, owing to the chaotic condition of the literature of the subject, omissions would occur.

But, after all proper exclusions and additions have been made, the total number of species of flowering plants utilized to any considerable extent by man in his civilized state does not exceed, in fact it does not quite reach, 1 per cent.

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in more than one category. He has also arranged the plants according to the countries *naturally producing them.*

*Useful Native Plants of Australia* (including Tasmania). By J. H. Maiden, F.L.S., Curator of the Technological Museum of New South Wales, Sydney. Sydney, 1889. See also note 19.

*Handbook of Commercial Geography.* By George G. Chisholm, M. A., B. Sc. London, 1889.

*New Commercial Plants,* with directions how to grow them to the best advantage. By Thomas Christy. London, Christy & Co.

*Dictionary* of popular names of the plants which furnish the natural and acquired wants of man. By John Smith, A. L. S. London, 1882.

*Cultivated Plants.* Their propagation and improvement. By F. W. Burbage. London, 1877.

*The Wanderings of Plants* and animals from their first home. By Victor Hehn, edited by James Steven Stallybrass. London, 1885.

*Researches into the Early History of Mankind* and the development of civilization. By Edward B. Tylor, D.C.L., L.L.D., F.R.S. 1878.

*The number of species of *Phænogamia* has been given by many writers as not far from 150,000. But the total number of species recognized by Bentham and Hooker in the *Genera Plantarum* (Durand's Index) is 100,220, in 210 Natural Orders and 8,417 genera.

†Dr. E. Lewis Sturtevant, to whose kindness I am indebted for great assistance in the matter of references, has placed at my disposal many of his notes on edible plants, etc. From his enumeration it appears that if we count all the plants which have been cultivated for food at one time or another, the list contains 1,192 species, but if we count all the plants which "either habitually or during famine periods are recorded to have been eaten," we obtain a list of no less than 4,690 species, or about 3½ per cent of all known species of plants. But, as Sir Joseph Hooker has said, the products of many plants though eatable, are not fit to eat.

The disproportion between the plants which are known and those which are used becomes much greater when we take into account the species of flowerless plants also. Of the 500 ferns and their allies we employ, for other than decorative purposes, only 5; the mosses and liverworts, roughly estimated at 500 species, have only 4 which are directly used by man. There are comparatively few algæ, fungi, or lichens which have extended use.

Therefore, when we take the flowering and flowerless together, the percentage of utilized plants falls far below the estimate made for the flowering alone.

Such a ratio between the number of species known and the number used justifies the inquiry which I have proposed for discussion at this time, namely, can the short list of useful plants be increased to advantage? If so, how?

This is a practical question; it is likewise a very old one. In one form or another, by one people or another, it has been asked from early times. In the dawn of civilization mankind inherited from savage ancestors certain plants, which had been found amenable to simple cultivation, and the products of these plants supplemented the spoils of the chase and of the sea. The question which we ask now was asked then. Wild plants were examined for new uses; primitive agriculture and horticulture extended their bounds in answer to this inquiry. Age after age has added slowly and cautiously to the list of cultivable and utilizable plants, but the aggregate additions have been, as we have seen, comparatively slight.

The question has thus no charm of novelty, but it is as practical to-day as in early ages. In fact, at the present time, in view of all the appliances at the command of modern science and under the strong light cast by recent biological and technological research, the inquiry which we propose assumes great importance. One phase of it is being attentively and systematically regarded in the great experiment stations, another phase is being studied in the laboratories of chemistry and pharmacy, while still another presents itself in the museums of economic botany.

Our question may be put in other words, which are even more practical. What present likelihood is there that our tables may, one of these days, have other vegetables, fruits, and cereals than those which we use now? What chance is there that new fibers may supplement or even replace those which we spin and weave, that woven fabrics may take on new vegetable colors, that flowers and leaves may yield new perfumes and flavors? What probability is there that new remedial agents may be found among plants neglected or now wholly unknown? The answer which I shall attempt is not in the nature of a prophecy; it can claim no rank higher than that of a reasonable conjecture.

At the outset it must be said that synthetic chemistry has made and is making some exceedingly short cuts across this field of research,

giving us artificial dyes, odors, flavors, and medicinal substances, of such excellence that it sometimes seems as if before long the old-fashioned chemical processes in the plant itself would play only a subordinate part. But although there is no telling where the triumphs of chemical synthesis will end, it is not probable that it will ever interfere essentially with certain classes of economic plants. It is impossible to conceive of a synthetic fiber or a synthetic fruit. Chemistry gives us fruit ethers and fruit acids, and after a while may provide us with a true artificial sugar and amorphous starch; but artificial fruits worth the eating, or artificial fibers worth the spinning, are not coming in our day.

Despite the extraordinary achievements of synthetic chemistry, the world must be content to accept, for a long time to come, the results of the intelligent labor of the cultivator of the soil and the explorer of the forest. Improvement of the good plants we now utilize, and the discovery of new ones, must remain the care of large numbers of diligent students and assiduous workmen. So that in fact our question resolves itself into this: Can these practical investigators hope to make any substantial advance?

It will be well to glance first at the manner in which our wild and cultivated plants have been singled out for use. We shall, in the case of each class, allude to the methods by which the selected plants have been improved, or their products fully utilized. Thus looking the ground over, although not minutely, we can see what new plants are likely to be added to our list. Our illustrations can at the best be only fragmentary.

We shall not have time to treat the different divisions of the subject in precisely the proportions which would be demanded by an exhaustive essay; an address on an occasion like this must pass lightly over some matters which other opportunities for discussion could properly examine with great fulness. Unfortunately, some of the minor topics which must be thus passed by possess considerable popular interest; one of these is the first subordinate question introductory to our task, namely, how were our useful cultivated and wild plants selected for use?

A study of the early history of plants employed for ceremonial purposes, in religious solemnities, in incantations, and for medicinal uses, shows how slender has sometimes been the claim of certain plants to the possession of any real utility. But some of the plants which have been brought to notice in these ways have afterwards been found to be utilizable in some fashion or other. This is often seen in the cases of the plants which have been suggested for medicinal use through the absurd doctrine of signatures.*

It seems clear that except in modern times useful plants have been selected almost wholly by chance, and it may well be said that a selec-

* *The Folk-Lore of Plants.* By T. F. Thiselton Dyer. 1889.

tion by accident is no selection at all. Nowadays the new selections are based on analogy. One of the most striking illustrations of the modern method is afforded by the utilization of bamboo fiber for electric lamps.

Some of the classes of useful plants must be passed by without present discussion, others alluded to slightly, while still other groups fairly representative of selection and improvement will be more fully described. In this latter class would naturally come, of course, the food plants known as

I.—THE CEREALS.

Let us look first at these. The species of grasses which yield these seed-like fruits, or, as we might call them for our purpose, seeds, are numerous;* 20 of them are cultivated largely in the Old World, but only six of them are likely to be very familiar to you, namely, wheat, rice, barley, oats, rye, and maize. The last of these is of American origin, despite doubts which have been cast upon it. It was not known in the Old World until after the discovery of the New. It has probably been very long in cultivation. The others all belong to the Old World. Wheat and barley have been cultivated from the earliest times; according to De Candolle, the chief authority in these matters, about four thousand years. Later came rye and oats, both of which have been known in cultivation for at least two thousand years. Even the shorter of these periods gives time enough for wide variation, and as is to be expected there are numerous varieties of them all. For instance, Vilmorin, in 1880, figured sixty-six varieties of wheat with plainly distinguishable characters.†

If the Chinese records are to be trusted, rice has been cultivated for a period much longer than that assigned by our history and traditions to the other cereals, and the varieties are correspondingly numerous. It is said that in Japan above three hundred varieties are grown on irrigated lands, and more than one hundred on uplands.‡

With the possible exception of rice, not one of the species of cereals is certainly known in the wild state.§ Now and then specimens have been gathered in the East which can be referred to the probable types from which our varieties have sprung, but doubt has been thrown upon every one of these cases. It has been shown conclusively that it is easy for a plant to escape from cultivation and persist in its new

* In Dr. Sturtevant's list, 88 species of *Gramineæ* are counted as food plants under cultivation, while the number of species in this order which can be or have been utilized as food amounts to 146. Our smaller number, 20, comprises only those which have been grown on a large scale anywhere.

† "In the Agricultural Museum at Poppelsdorf, 600 varieties are exhibited."

‡ E. L. S. in letter. Quoted from Seedsman's catalogue.

§ The best account of the early history of these and other cultivated plants can be found in the classical work of De Candolle "*Origine des Plantes Cultivées* (Paris) translated in the International series, *History of Cultivated Plants* (N. Y.). The reader should consult also Darwin's *Animals and Plants under Domestication*.

home even for a long time in a near approximation to cultivated form. Hence, we are forced to receive all statements regarding the wild forms with caution. But it may be safely said that if all the varieties of cereals which we now cultivate were to be swept out of existence, we could hardly know where to turn for wild species with which to begin again. We could not know with certainty.

To bring this fact a little more vividly to our minds, let us suppose a case. Let us imagine that a blight without parallel has brought to extinction all the forms of wheat, rice, rye, oats, barley, and maize, now in cultivation, but without affecting the other grasses or any other form of vegetable food. Mankind would be obliged to subsist upon the other kindly fruits of the earth; upon root crops, tubers, leguminous seeds, and so on. Some of the substitutions might be amusing in any other time than that of a threatened famine. Others would be far from appetizing under any condition, and only a few would be wholly satisfying even to the most pronounced vegetarian. In short, it would seem from the first, that the cereals fill a place occupied by no other plants. The composition of the grains is theoretically and practically almost perfect as regards food ratio between the nitrogenous matters and the starch group; and the food value, as it is termed, is high. But aside from these considerations, it would be seen that for safety of preservation through considerable periods, and for convenience of transportation, the cereals take highest rank. Pressure would come from every side to compel us to find equivalents for the lost grains. From this predicament I believe that the well-equipped Experiment Stations and the Agricultural Departments in Europe and America would by and by extricate us. Continuing this hypothetical case, let us next inquire how the stations would probably go to work in the up-hill task of making partially good a well-nigh irreparable loss.

The whole group of relatives of the lost cereals would be passed in strict review. Size of grain, strength and vigor and plasticity of stock, adaptability to different surroundings, and flexibility in variation would be examined with scrupulous care.

But the range of experiment would, under the circumstances, extend far beyond the relatives of our present cereals. It would embrace an examination of the other grasses which are even now cultivated for their grains, but which are so little known outside of their own limit that it is a surprise to hear about them. For example, the millets, great and small, would be investigated. These grains, so little known here, form an important crop in certain parts of the East. One of the leading authorities on the subject* states that the millets constitute

* *Food grains of India*, A. H. Church, London, 1886, p. 31. In this instructive work the reader will find much information regarding the less common articles of food. Of *Panicum frumentaceum* Prof. Georgeson states in a letter that it is grown in Japan for its grain which is used for food, but here would take rank as a fodder plant.

"a more important crop" in India "than either rice or wheat, and are grown more extensively, being raised from Madras in the south to Rajputana in the north. They occupy about 83 per cent of the food grain area in Bombay and Sinde, 41 per cent in the Punjab, 39 per cent in the Central Provinces," "in all about 30,000,000 acres."

Having chosen proper subjects for experimenting, the cultivators would make use of certain well-known principles. By simple selection of the more desirable seeds, strains would be secured to suit definite wants, and these strains would be kept as races, or attempts would be made to intensify wished-for characters. By skillful hybridizing of the first, second, and higher orders, tendencies to wider variation would be obtained and the process of selection considerably expedited.*

It is out of our power to predict how much time would elapse before satisfactory substitutes for our cereals could be found. In the improvement of the grains of grasses other than those which have been very long under cultivation, experiments have been few, scattered, and indecisive. Therefore we are as badly off for time ratios as are the geologists and archæologists, in their statements of elapsed periods. It is impossible for us to ignore the fact that there appear to be occasions in the life of a species when it seems to be peculiarly susceptible to the influences of its surroundings.† A species, like a carefully laden ship, represents a balancing of forces within and without. Disturbance may come through variation from within, as from a shifting of the cargo, or in some cases from without. We may suppose both forces to be active in producing variation, a change in the internal condition rendering the plant more susceptible to any change in its surroundings. Under the influence of any marked disturbance, a state of unstable equilibrium may be brought about, at which times the species, as such, is easily acted upon by very slight agencies.

One of the most marked of these derangements is a consequence of cross-breeding within the extreme limits of varieties. The resultant forms in such cases can persist only by close breeding or by propagation from buds or the equivalents of buds. Disturbances like these arise unexpectedly in the ordinary course of nature, giving us sports of various kinds. These critical periods however are not unwelcome, since skillful cultivators can take advantage of them. In this very field much has been accomplished. An attentive study of the saga-

* In order to avoid possible misapprehension, it should be stated that there are a few persons who hold that at least some of our cereals, and other cultivated plants, for that matter, have not undergone material improvement but are essentially unmodified progeny. Under this view, if we could look back into the farthest past, we should see our cereals growing wild and in such admirable condition that we should unhesitatingly select them for immediate use. This extreme position is untenable. Again, there are a few extremists who hold that some plants under cultivation have reached their culminating point, and must now remain stationary or begin to retrograde.

† Gray's *Botanical Text Book*, vols. I and II.

cious work done by Thomas Andrew Knight shows to what extent this can be done.* But we must confess that it would be absolutely impossible to predict with certainty how long or how short would be the time before new cereals or acceptable equivalents for them would be provided. Upheld by the confidence which I have in the intelligence, ingenuity, and energy of our Experiment Stations, I may say that the time would not probably exceed that of two generations of our race, or half a century.

In now laying aside our hypothetical illustration, I venture to ask why it is that our Experiment Stations and other institutions dealing with plants and their improvement do not undertake investigations like those which I have sketched? Why are not some of the grasses other than our present cereals studied with reference to their adoption as food grains? One of these species will naturally suggest itself to you all, namely, the Wild Rice of the Lakes.† Observations have shown that were it not for the difficulty of harvesting these grains which fall too easily when they are ripe, they might be utilized. But attentive search might find or educe some variety of *Zizania* with a more persistent grain and a better yield. There are two of our seashore grasses which have excellent grains, but are of small yield Why are not these, or better ones which might be suggested by observation, taken in hand?

The reason is plain. We are all content to move along in lines of least resistance, and are disinclined to make a fresh start. It is merely leaving well enough alone, and so far as the cereals are concerned it is indeed well enough. The generous grains of modern varieties of wheat and barley compared with the well-preserved charred vestiges found in Greece by Schliemann,‡ and in the lake dwellings,§ are satisfactory in

* *A Selection from the Physiological and Horticultural Papers,* published in the Transactions of the Royal and Horticultural Societies, by the late Thomas Andrew Knight, esq., president of the Hort. Soc. London (London), 1841.

† *Illustrations of the Manners and Customs and Condition of the North American Indians.* By George Catlin, London, 1876. A reprint of the account published in 1841 of travels in 1832–1840. "Plate 278 is a party of Sioux, in bark canoes (purchased of the Chippewas), gathering the wild rice, which grows in immense fields around the shores of the rivers and lakes of these northern regions, and used by the Indians as an article of food. The mode of gathering it is curious, and, as seen in the drawing, one woman paddles the canoe, whilst another, with a stick in each hand, bends the rice over the canoe with one and strikes it with the other, which shakes it into the canoe, which is constantly moving along until it is filled." Vol. II, p. 208.

‡ Schliemann's carbonized specimens exhumed in Greece are said to be "very hard, fine-grained, sharp, very flat on grooved side, different from any wheats now known." *Am. Antiq.*, 1880, 66. The carbonized grains in the Peabody Museum at Cambridge, Mass., are small.

§ *Prehistoric Times,* as illustrated by ancient remains and the manners and customs of modern savages. By John Lubbock, Bart. (New York), 4th edn., 1886. "Three varieties of wheat were cultivated by the Lake Dwellers, who also possessed two kinds of barley and two of millet. Of these the most ancient and most important

every respect. Improvements however are making in many directions; and in the cereals we now have, we possess far better and more satisfactory material for further improvement, both in quality and as regards range of distribution, than we could reasonably hope to have from other grasses.

From the cereals we may turn to the interesting groups of plants comprised under the general term.

### II.—VEGETABLES.

Under this term it will be convenient for us to include all plants which are employed for culinary purposes or for table use, such as salads and relishes.

The potato and sweet potato, the pumpkin and squash, the red or capsicum peppers, and the tomato are of American origin.

All the others are most probably natives of the Old World. Only one plant coming in this class has been derived from southern Australasia, namely, New Zealand spinach (*Tetragonia*).

Among the vegetables and salad plants longest in cultivation we may enumerate the following: Turnip, onion, cabbage, purslane, the large bean (Faba), chick-pea, lentil, and one species of pea—garden pea. To these an antiquity of at least four thousand years is ascribed.

Next to these, in point of age, come the radish, carrot, beet, garlic, garden-cress, and celery, lettuce, asparagus, and the leek. Three or four leguminous seeds are to be placed in the same category, as are also the black peppers.

Of more recent introduction, the most prominent are the parsnip, oyster plant, parsley, artichoke, endive, and spinach.

From these lists I have purposely omitted a few which belong exclusively to the tropics, such as certain yams.

The number of varieties of these vegetables is astounding. It is of course impossible to discriminate between closely allied varieties which have been introduced by gardeners and seedsmen under different names, but which are essentially identical, and we must therefore have recourse to a conservative authority, Vilmorin,* from whose work a few

were the six-rowed barley and small 'Lake Dwellers'" wheat. The discovery of Egyptian wheat (*Triticum turgidum*) at Wangen and Robenhausen is particularly interesting. Oats were cultivated during the bronze age, but are absent from all the stone age villages. Rye was also unknown," p. 216. "Wheat is most common, having been discovered at Merlen, Moosseedorf, and Wangen. At the latter place, indeed, many bushels of it were found, the grains being in large, thick lumps. In other cases the grains are free, and without chaff, resembling our present wheat in size and form, while more rarely they are still in the ear." One hundred and fifteen species of plants have been identified. Heer Keller.

* *Les Plantes Potagères*, Vilmorin, Paris. Translated into English under the direction of W. Robinson, editor of the (London) "Garden," 1885, and entitled *The Vegetable Garden*.

examples have been selected. The varieties which he accepts are sufficiently well distinguished to admit of description, and in most instances of delineation, without any danger of confusion. The potato has, he says, innumerable varieties, of which he accepts forty as easily distinguishable and worthy of a place in a general list, but he adds also a list, comprising of course synonyms, of thirty-two French, twenty-six English, nineteen American, and eighteen German varieties. The following numbers speak for themselves, all being selected in the same careful manner as those of the potato; celery more than twenty; carrot more than thirty; beet, radish, and potato more than forty; lettuce and onion more than fifty; turnip more than seventy; cabbage, kidney bean, and garden pea more than one hundred.

The amount of horticultural work which these numbers represent is enormous. Each variety established as a race (that is, a variety which comes true to seed) has been evolved by the same sort of patient care and waiting which we have seen is necessary in the case of cereals, but the time of waiting has not been as a general thing so long.

You will permit me to quote from Vilmorin* also an account of a common plant, which will show how wide is the range of variation and how obscure are the indications in the wild plant of its available possibilities. The example shows how completely hidden are the potential variations useful to mankind.

"Cabbage, a plant which is indigenous in Europe and western Asia, is one of the vegetables which has been cultivated from the earliest time. The ancients were well acquainted with it, and certainly possessed several varieties of the head-forming kinds. The great antiquity of its culture may be inferred from the immense number of varieties which are now in existence, and from the very important modifications which have been produced in the characteristics in the original or parent plant.

"The wild cabbage, such as it now exists on the coasts of England and France, is a perennial plant with broad-lobed, undulated, thick, smooth leaves, covered with a glaucus bloom. The stem attains a height of from nearly 2½ to over 3 feet, and bears at the top a spike of yellow or sometimes white flowers. All the cultivated varieties present the same peculiarities in their infloresence, but up to the time of flowering they exhibit the most marked differences from each other and from the original wild plant. In most of the cabbages it is chiefly the leaves that are developed by cultivation; these for the most part become imbricated or overlap one another closely, so as to form a more or less compact head, the heart or interior of which is composed of the central undeveloped shoot and the younger leaves next it. The shape of the head is spherical, sometimes flattened, sometimes conical. All the varieties which form heads in this way are known by the general name of

* *Loc. cit.*, English edition, p. 101.

cabbages, while other kinds, with large branching leaves which never form heads, are distinguished by the name of borecole or kale.

"In some kinds the flower stems have been so modified by culture as to become transformed into a thick, fleshy, tender mass, the growth and enlargement of which are produced at the expense of the flowers which are absorbed and rendered abortive. Such are the broccolis and cauliflowers."

But this plant has other transformations. "In other kinds the leaves retain their ordinary dimensions, while the stem or principal root has been brought by cultivation to assume the shape of a large ball or turnip, as in the case of the plants known as Kohl-Rabi and turnip-rooted cabbage or Swedish turnip. And lastly, there are varieties in which cultivation and selection have produced modifications in the ribs of the leaves, as in the Couve Tronchuda, or in the axilary shoots (as in Brussels sprouts), or in several organs together, as in the marrow kales, and the Neapolitan curled kale."

Here are important morphological changes like those to which Prof. Bailey has called attention in the case of the tomato.

Suppose we are strolling along the beach at some of the seaside resorts of France, and should fall in with this coarse, cruciferous plant, with its sprawling leaves and strong odor. Would there be anything in its appearance to lead us to search for its hidden merits as a food plant? What could we see in it which would give it a preference over a score of other plants at our feet? Again, suppose we are journeying in the highlands of Peru, and should meet with a strong-smelling plant of the night-shade family, bearing a small, irregular fruit of sub-acid taste and of peculiar flavor. We will further imagine that the peculiar taste strikes our fancy, and we conceive that the plant has possibilities as a source of food. We should be led by our knowledge of the potato, probably a native of the same region, to think that this allied plant might be safely transferred to a northern climate, but would there be promise of enough future usefulness in such a case as this to warrant our carrying the plant north as an article of food? Suppose, further, we should ascertain that the fruit in question was relished not only by the natives of its home, but that it had found favor among the tribes of South Mexico and Central America, and had been cultivated by them until it had attained a large size, should we be strengthened in our venture? Let us go one step further still. Suppose that having decided upon the introduction of the plant, and having urged everybody to try it, we should find it discarded as a fruit, but taking a place in gardens as a curiosity under an absurd name, or as a basis for preserves and pickles; should we not look upon our experiment in the introduction of this new plant as a failure? This is not a hypothetical case.

The tomato,* the plant in question, was cultivated in Europe as long ago as 1554;† it was known in Virginia in 1781, and in the Northern States in 1785; but it found its way into favor slowly, even in this land of its origin. A credible witness states that in Salem it was almost impossible to induce people to eat or even taste of the fruit. And yet, as you are well aware, its present cultivation on an enormous scale in Europe and this country is scarcely sufficient to meet the increasing demand.

A plant which belongs to the family of the tomato has been known to the public under the name of the strawberry tomato. The juicy yellow or orange-colored fruit is inclosed in a papery calyx of large size. The descriptions which were published when the plant was placed on the market were attractive, and were not exaggerated to a misleading extent. But, as you all know, the plant never gained any popularity. If we look at these two cases carefully, we shall see that what appears to be caprice on the part of the public is at bottom common sense. The cases illustrate as well as any which are at command the difficulties which surround the whole subject of the introduction of new foods.

Before asking specifically in what direction we shall look for new vegetables, I must be pardoned for calling attention, in passing, to a very few of the many which are already in limited use in Europe and this country, but which merit a wider employment. Cardon, or cardoon; celeriac, or turnip-rooted celery; fetticus, or corn salad; martynia; salsify; sea kale, and numerous small salads, are examples of neglected treasures of the vegetable garden.

The following, which are even less known, may be mentioned as fairly promising:‡

(1) *Arracacia esculenta*, called Arracacha, belonging to the parsley family. It is extensively cultivated in some of the northern States of South America. The stems are swollen near the base, and produce

*According to notes made by Mr Manning, Sec. Massachusetts Horticultural Society (*Hist. Mass. Hort. Society*), the tomato was introduced into Salem, Mass., about 1802 by Michele Felice Corné, an Italian painter, but he found it difficult to persuade people even to taste the fruit (Felt's *Annals of Salem*, vol. II, 631). It was said to have been introduced into Philadelphia by a French refugee from San Domingo, in 1798. It was used as an article of food in New Orleans in 1812, but was not sold in the markets of Philadelphia until 1829. It did not come into general use in the North until some years after the last named date.

† "In Spain and those hot regions they use to eat the (love) apples prepared and boiled with pepper, salt, and olives; but they yield very little nourishment to the bodies, and the same nought and corrupt. Likewise they doe eat the apples with oile, vinegar, and pepper mixed together for sauce to their meat even as we in these cold countries do mustard." Gerard's *Herbal*, 346.

‡ *Commercial Botany of the Nineteenth Century.* By John R. Jackson, A. L. S. Cassell and Company. London, 1890. Mr. Jackson, who is the curator of the museums, Royal Gardens, Kew, has embodied in this treatise a great amount of valuable information, well arranged for ready reference.

tuberous enlargements filled with an excellent starch. Although the plant is of comparatively easy cultivation, efforts to introduce it into Europe have not been successful, but it is said to have found favor in both the Indies, and may prove useful in our Southern States.

(2) *Ullucus* or Ollucus, another tuberous-rooted plant from nearly the same region, but belonging to the beet or spinach family. It has produced tubers of good size in England, but they are too waxy in consistence to dispute the place of the better tubers of the potato. The plant is worth investigating for our hot, dry lands.

(3) A tuber-bearing relative of our common hedge nettle, or *Stachys*, is now cultivated on a large scale at Crosnes, in France, for the Paris market. Its name in Paris is taken from the locality where it is now grown for use. Although its native country is Japan, it is called by some seedsmen Chinese artichoke. At the present stage of cultivation the tubers are small and are rather hard to keep, but it is thought "that both of these defects can be overcome or evaded."* Experiments indicate that we have in this species a valuable addition to our vegetables. We must next look at certain other neglected possibilities.

Dr. Edward Palmer,† whose energy as a collector and acuteness as an observer are known to you all, has brought together very interest-

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* *Gard. Chron.*, 1888.

† *Department of Agriculture Report* for 1870, p. 404–428. Only those are here copied from Dr. Palmer's list which he expressly states are extensively used.

Ground nut (*Apios tuberosa*); *Æsculus Californica; Agave Americana; Nuphar advena:* prairie potato (*Psoralea esculenta*); *Scirpus lacustris; Sagittaria variabilis;* Kamass-root (*Camassia esculenta*); *Solanum Fendleri* (supposed by him to be the original of the cultivated potato); acorns of various sort; mesquit (*Algarobia glandulosa*); *Juniperus occidentalis;* nuts of *Carya, Juglans,* etc.; screw-bean (*Strombocarpus pubescens*); various cactaceæ; *Yucca;* cherries and many wild berries; *Chenopodium album.*, etc. *Psoralea esculenta*=prairie potato, or bread root. Palmer in *Agricultural Report*, 1870, p. 402.

The following from Catlin, *l. c.* I, p. 122:

"Corn and dried meat are generally laid up in the fall in sufficient quantities to support them through the winter. These are the principal articles of food during that long and inclement season; and in addition to them, they oftentimes have in store great quantities of dried squashes, and dried 'pommes blanches,' a kind of turnip which grows in great abundance in those regions. - - - These are dried in great quantities and pounded into a sort of meal and cooked with dried meat and corn. Great quantities also are dried and laid away in store for the winter season, such as buffalo berries, service berries, strawberries, and wild plums. In addition to this we had the luxury of service berries without stint; and the buffalo bushes, which are peculiar to these northern regions, lined the banks of the river and the defiles in the bluffs, sometimes for miles together, forming almost impassable hedges, so loaded with the weight of their fruit that their boughs were seen everywhere gracefully bending down or resting on the ground. This last shrub (*Shepherdia*), which may be said to be the most beautiful ornament that decks out the wild prairies, forms a striking contrast to the rest of the foliage, from the blue appearance of its leaves, by which it can be distinguished for miles in distance. The fruit which it produces in such incredible profusion, hanging in clusters to every limb and to every twig, is about the size of ordinary currants and not unlike them in

ing facts relative to the food plants of our North American aborigines. Among the plants described by him there are a few which merit careful investigation. Against all of them, however, there lie the objections mentioned before, namely:

(1) The long time required for their improvement, and

(2) The difficulty of making them acceptable to the community, involving

(3) The risk of total and mortifying failure.

In the notes to this address the more prominent of these are enumerated.

In 1854 the late Prof. Gray called attention to the remarkable relations which exist between the plants of Japan and those of our Eastern coast. You will remember that he not only proved that the plants of the two regions had a common origin, but also emphasized the fact that many species of the two countries are almost identical. It is to that country which has yielded us so many useful and beautiful plants that we turn for new vegetables to supplement our present food resources. One of these plants, namely, *Stachys*, has already been mentioned as rather promising. There are others which are worth examination and perhaps acquisition.

One of the most convenient places for a preliminary examination of the vegetables of Japan is at the railroad stations on the longer lines, for instance, that running from Tokio to Kobe. For native consumption there are prepared luncheon boxes of two or three stories, provided with the simple and yet embarrassing chopsticks. It is worth the shock it causes one's nerves to invest in these boxes and try the vegetable contents. The bits of fish, flesh, and fowl, which one finds therein can be easily separated and discarded, upon which there will remain a few delicacies. The pervading odor of the box is that of aromatic vinegar. The generous portion of boiled rice is of excellent quality, with every grain well softened and distinct, and this without anything else would suffice for a tolerable meal. In the boxes which have fallen under my observation there were sundry boiled roots, shoots,

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color and even in flavor; being exceedingly acid, almost unpalatable until they are bitten by frost of autumn, when they are sweetened and their flavor delicious, having to the taste much the character of grapes, and I am almost to think would produce excellent wine." (George Catlin's illustrations and manners, customs, and condition of the *North American Indians*, vol. I, p. 72.)

For much relative to the food of our aborigines, especially of the western coast, consult the *Native Races of the Pacific States of North America*, by H. H. Bancroft (New York), 1875. The following, from vol. I, p. 538, indicates that inaccuracies have crept into the work: "From the earliest information we have of these nations" (the author is speaking of the New Mexicans), "they are known to have been tillers of the soil; and though the implements used and their methods of cultivation were both simple and primitive, cotton, corn, *wheat*, beans, and many varieties of fruits which constituted their principal food were raised in abundance."

Wheat was not grown on the American continent until after the landing of the first explorers.

and seeds which were not recognizable by me in their cooked form. Prof. Georgeson, formerly of Japan, has kindly identified some of these for me,* but he says, "There are doubtless many others used occasionally."

One may find sliced lotus roots, roots of large burdock, lily bulbs, shoots of ginger, pickled green plums, beans of many sorts, boiled chestnuts, nuts of the gingko tree, pickled greens of various kinds, dried cucumbers, and several kinds of sea-weeds. Some of the leaves and roots are cooked in much the same manner as beet-roots and beet-leaves are by us, and the general effect is not unappetizing. The boiled shoots are suggestive of only the tougher ends of asparagus. On the whole, I do not look back on Japanese railway luncheons with any longing which would compel me to advocate the indiscriminate introduction of the constituent vegetables here.

But when the same vegetables are served in native inns, under more favorable culinary conditions, without the flavor of vinegar and of the pine wood of the luncheon boxes, they appear to be worthy of a trial in our horticulture, and I therefore deal with one or two in greater detail.

Prof. Georgeson, whose advantages for acquiring a knowledge of the useful plants of Japan have been unusually good, has placed me under great obligations by communicating certain facts regarding some of the more promising plants of Japan which are not now used here. It should be said that several of these plants have already attracted the notice of the Agricultural Department in this country.

The soy bean (*Glycine hispida*). This species is known here to some extent, but we do not have the early and best varieties. These beans replace meat in the diet of the common people.

Mucuna (*Mucuna capitata*) and Dolichos (*Dolichos cultratus*) are pole beans possessing merit.

*Dioscorea*; there are several varieties with palatable roots. Years ago one of these was spoken of by the late Dr. Gray as possessing "excellent roots, if one could only dig them."

*Colocasia antiquorum* has tuberous roots, which are nutritious.

* Pickled daikon, the large radish, often grated; ginger roots, Shoga; beans (*Glycine hispida*), many kinds, and prepared in many ways; beans (*Dolichos cultratus*), cooked in rice and mixed with it; sliced Hasu, lotos roots; lily bulbs, boiled whole and the scales torn off as they are eaten; pickled green plums, (Umeboshi) colored red in the pickle, by the leaves of *Perilla arguta* (Shiso); sliced and dried cucumbers, Kiuri; pieces of Gobo—roots of *Lappa major;* Rakkio, bulbs of *Allium Bakeri*, boiled in Shogu; grated Wasabi, stem of *Eutrema Wasabi;* watercress, midzu-tagarashi (not often); also sometimes pickled geeens of various kinds, and occasionally chestnut kernels boiled and mixed with a kind of sweet sauce; nut of the Ginkgo tree; several kinds of sea-weeds are also very commonly served with the rice. (Prof. C. C. Georgeson in letter.)

*Conophallus Konjak* has a large bulbous root, which is sliced, dried, and beaten to a powder. It is an ingredient in cakes.

*Aralia cordata* is cultivated for the shoots, and used as we use asparagus.

*Œnanthe stolonifera* and *Cryptotænia Canadensis* are palatable salad plants, the former being used also as greens.

There is little hope, if any, that we shall obtain from the hotter climates for our southern territory new species of merit. The native markets in the tropical cities like Colombo, Batavia, Singapore, and Saigon, are rich in fruits, but outside of the native plants bearing these nearly all the plants appear to be wholly in established lines of cultivation, such, for instance, as members of the gourd and night-shade families.

Before we leave the subject of our coming vegetables, it will be well to note a naïve-caution enjoined by Vilmorin in his work, *Les Plantes Potagères.**

"Finally," he says, "we conclude the article devoted to each plant with a few remarks on the uses to which it may be applied and on the parts of the plants which are to be so used. In many cases such remarks may be looked upon as idle words, and yet it would sometimes have been useful to have them when new plants were cultivated by us for the first time. For instance, the giant edible burdock of Japan (*Lappa edulis*) was for a long time served up on our tables only as a wretchedly poor spinach, because people would cook the leaves, whereas, in its native country, it is only cultivated for its tender fleshy roots."

I trust you are not discouraged at this outlook for our coming vegetables.

Two groups of improvable food-plants may be referred to before we pass to the next class, namely, edible fungi and the beverage plants. All botanists who have given attention to the matter agree with the late Dr. Curtis of North Carolina that we have in the unutilized mushrooms an immense amount of available nutriment of a delicious quality. It is not improbable that other fungi than our common "edible mushroom" will by and by be subjected to a careful selection.

The principal beverage-plants, tea, coffee and chocolate, are all attracting the assiduous attention of cultivators. The first of these plants is extending its range at a marvelous rate of rapidity through India and Ceylon; the second is threatened by the pests which have almost exterminated it in Ceylon, but a new species, with crosses therefrom, is promising to resist them successfully; the third, chocolate, is every year passing into lands farther from its original home. To these have been added the kola (of a value as yet not wholly determined), and others are to augment the short list.

* *Loc. cit.* Preface in English edition.

III.—FRUITS.

Botanically speaking, the cereal grains of which we have spoken are true fruits, that is to say, are ripened ovaries, but for all practical purposes they may be regarded as seeds. The fruits, of which mention is now to be made, are those commonly spoken of in our markets as fruits.

First of all, attention must be called to the extraordinary changes in the commercial relations of fruits by two direct causes:

(1) The canning industry, and

(2) Swift transportation by steamers and railroads.

The effects of these two agencies are too well known to require more than this passing mention. By them the fruits of the best fruit-growing countries are carried to distant lands in quantities which surprise all who see the statistics for the first time. The ratio of increase is very startling. Take, for instance, the figures given by Mr. Morris at the time of the great Colonial and Indian Exhibition, in London. Compare double decades of years:

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| 1845 | £886,888 |
| 1865 | 3,185,984 |
| 1885 | 7,587,523 |

In the Colonial Exhibition at London, in 1886, fruits from the remote colonies were exhibited under conditions which proved that, before long, it may be possible to place such delicacies as the cherimoyer, the sweet-sop, rambutan, mango, and mangosteen at even our most northern seaports. Furthermore, it seems to me likely that with an increase in our knowledge with regard to the microbes which produce decay, we may be able to protect the delicate fruits from injury for any reasonable period. Methods which will supplement refrigeration are sure to come in the very near future, so that even in a country so vast as our own the most perishable fruits will be transported through its length and breadth without harm.

The canning industry and swift transportation are likely to diminish zeal in searching for new fruits, since, as we have seen in the case of the cereals, we are prone to move in lines of least resistance and leave well enough alone.

To what extent are our present fruits likely to be improved? Even those who have watched the improvement in the quality of some of our fruits, like oranges, can hardly realize how great has been the improvement within historic times in the character of certain pears, apples, and so on.

The term historic is used advisedly, for there are pre-historic fruits which might serve as a point of departure in the consideration of the question. In the ruins of the lake dwellings in Switzerland* charred

* "Carbonized apples have been found at Wangen, sometimes whole, sometimes cut in two, or, more rarely, into four pieces and evidently dried and put aside for winter use. - - - They are small and generally resemble those which still grow

apples have been found, which are in some cases plainly of small size, hardly equalling ordinary crab-apples. But, as Dr. Sturtevant has shown, in certain directions there has been no marked change of type; the change is in quality.

In comparing the earlier descriptions of fruits with modern accounts it is well to remember that the high standards by which fruits are now judged are of recent establishment. Fruits which would once have been esteemed excellent would to-day be passed by as unworthy of regard.

It seems probable that the list of seedless fruits will be materially lengthened, provided our experimental horticulturists make use of the material at their command. The common fruits which have very few or no seeds are the banana, pineapple, and certain oranges. Others mentioned by Mr. Darwin as well known are the bread-fruit, pomegranate, azarole or Neapolitan medlar, and date palms. In commenting upon these fruits, Mr. Darwin* says that most horticulturists "look at the great size and anomalous development of the fruit as the cause and sterility as the result," but he holds the opposite view as more probable; that is, that the sterility, coming about gradually, leaves free for other growth the abundant supply of building material which the forming seed would otherwise have. He admits however that "there is an antagonism between the two forms of reproduction, by seeds and by buds, when either is carried to an extreme degree, which is independent of any incipient sterility."

Most plant hybrids are relatively infertile, but by no means wholly sterile. With this sterility there is generally augmented vegetative vigor, as shown by Nägeli. Partial or complete sterility and corresponding luxuriance of root, stem, leaves, and flower may come about in other obscure ways, and such cases are familiar to botanists.† Now, it seems highly probable that either by hybridizing directed to this special end, or by careful selection of forms indicating this tendency to the correlated changes, we may succeed in obtaining important additions to our seedless or nearly seedless plants. Whether the ultimate profit would be large enough to pay for the time and labor involved is a question which we need not enter into; there appears to me no reasonable doubt that such efforts would be successful. There is no reason in the nature of things why we should not have strawberries without the so-called seeds, blackberries and raspberries with only delicious pulp, and large grapes as free from seeds as the small ones which we call "currants," but which are really grapes from Corinth.

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wild in the Swiss forests; at Robenhausen, however, specimens have occurred which are of larger size and probably cultivated. No trace of the vine, the walnut, the cherry, or the damson has yet been met with, but stones of the wild plum and the *Prunus padus* have been found." Lubbock, *loc. cit.*, p. 217.

* *Animals and Plants under Domestication* (Am. Ed.), vol. II. p. 205–209.

† Gray's *Botanical Text Book*.

These and the coreless apples and pears of the future, the stoneless cherries and plums, like the common fruits before mentioned, must be propagated by bud division, and be open to the tendency to diminished strength said to be the consequence of continued bud propagation. But this bridge need not be crossed until we come to it. Bananas have been perpetuated in this way for many centuries, and pineapples since the discovery of America, so that the borrowed trouble alluded to is not threatening. First we must catch our seedless fruits.

Which of our wild fruits are promising subjects for selection and cultivation?

Mr. Crozier, of Michigan, has pointed out* the direction in which this research may prove most profitable. He enumerates many of our small fruits and nuts which can be improved.

Another of our most careful and successful horticulturists believes that the common blueberry and its allies are very suitable for this purpose and offer good material for experimenting. The sugar-plum, or so-called shad-bush, has been improved in many particulars, and others can be added to this list.

But again we turn very naturally to Japan, the country from which our gardens have received many treasures. Referring once more to Prof. Georgeson's studies,† we must mention the varieties of Japanese apples, pears, peaches, plums, cherries and persimmons. The persimmons are already well known in some parts of our country under the name "kaki," and they will doubtless make rapid progress in popular favor.

The following are less familiar:

*Actinidia arguta* and *volubilis*, with delicious berries;

*Stauntonia*, an evergreen vine yielding a palatable fruit;

*Myrica rubra*, a small tree with an acidulous juicy fruit;

*Elæagnus umbellata*, with berries for preserves.

The active and discriminating horticultural journals in America and Europe are alive to the possibilities of new Japanese fruits, and it can not be very long before our list is considerably increased.

It is absolutely necessary to recollect that in most cases variations are slight. Dr. Masters and Mr. Darwin have called attention to this and have adduced many illustrations, all of which show the necessity of extreme patience and caution. The general student curious in such matters can have hardly any task more instructive than the detection of the variations in such common plants as the blueberry, the wild cherry, or the like. It is an excellent preparation for a practical study of the variations in our wild fruits suitable for selection.

It was held by the late Dr. Gray that the variations in nature by which species have been evolved were led along useful lines, a view

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* *American Garden*, N. Y. 1890–'91.

† *American Garden*, N. Y. 1891.

which Mr. Darwin regretted he could not entertain. However this may be, all acknowledge that by the hand of the cultivator variations can be led along useful lines; and furthermore the hand which selects must uphold them in their unequal strife. In other words, it is one thing to select a variety and another to assist it in maintaining its hold upon existence. Without the constant help of the cultivator who selects the useful variety, there comes a reversion to the ordinary specific type which is fitted to cope with its surroundings.

I think you can agree with me that the prospect for new fruits and for improvements in our established favorites is fairly good.

## IV.—TIMBERS AND CABINET WOODS.

Can we look for new timbers and cabinet woods? Comparatively few of those in common use are of recent introduction. Attempts have been made to bring into great prominence some of the excellent trees of India and Australia which furnish wood of much beauty and timber of the best quality. A large proportion of all the timbers of the South Seas are characterized by remarkable firmness of texture and high specific gravity.* The same is noticed in many of the woods of the Indies. A few of the heavier and denser sorts, like jarrah, of West Australia, and sabicu, of the Caribbean Islands, have met with deserved favor in England, but the cost of transportation militates against them. It is a fair question whether, in certain parts of our country, these trees and others which can be utilized for veneers may not be cultivated to advantage. Attention should be again called to the fact that many plants succeed far better in localities which are remote from their origin, but where they find conditions substantially like those which they have left. This fact, to which we must again refer in detail with regard to certain other classes of plants, may have some bearing upon the introduction of new timber trees. Certain drawbacks exist with regard to the timber of some of the more rapidly growing hard-wood trees which have prevented their taking a high place in the scale of values in mechanical engineering.

One of the most useful soft-wooded trees in the world is the kauri. It is restricted in its range to a comparatively small area in the North Island of New Zealand. It is now being cut down with a recklessness which is as prodigal and shameful as that which has marked our own treatment of forests here. It should be said however that this destruction is under protest, in spite of which it would seem to be a question of only a few years when the great kauri groves of New Zealand will be a thing of the past. Our energetic forest department has on its hands problems just like this which perplexes one of the new lands of the south. The task in both cases is double, to preserve the old treasures and to bring in new.

* *Useful Native Plants of Australia*, by J. H. Maiden, Sydney.

The energy shown by Baron von Mueller, the renowned Government botanist of Victoria, and by various forest departments, in encouraging the cultivation of timber trees will assuredly meet with success; one can hardly hope that this success will appear fully demonstrated in the lifetime of those now living, but I can not think that many years will pass before the promoters of such enterprises may take fresh courage.

In a modest structure in the city of Sidney, New South Wales, Mr. Maiden* has brought together, under great difficulties, a large collection of the useful products of the vegetable kingdom as represented in Australia. It is impossible to look at the collection of woods in that museum or at the similar and more showy one in Kew, without believing that the field of forest culture must receive rich material from the Southern Hemisphere.

Before leaving this part of our subject, it may be well to take some illustrations in passing, to show how important is the influence exerted upon the utilization of vegetable products by causes which may at first strike one as being rather remote:

(1) Photography makes use of the effect of light on chromatized gelatin to produce under a negative the basis of relief plates for engraving. The degree of excellence reached in modifications of this simple device has distinctly threatened the very existence of wood engraving, and hence follows a diminished degree of interest in boxwood and its substitutes.

(2) Iron, and in its turn steel, is used in shipbuilding, and this renders of greatly diminished interest all questions which concern the choice of different oaks, and similar woods.

(3) But on the other hand there is increased activity in certain directions, best illustrated by the extraordinary development of the chemical methods for manufacturing wood pulp. By the improved processes, strong fibers suitable for fine felting on the screen and fit for the best grades of certain lines of paper are given to us from rather inferior sorts of wood. He would be a rash prophet who should venture to predict what will be the future of this wonderful industry, but it is plain that the time is not far distant when acres now worthless may be covered by trees under cultivation, growing for the pulp-maker.

There is no department of economic botany more promising in immediate results than that of arboriculture.

## V.—VEGETABLE FIBERS.

The vegetable fibers known to commerce are either plant hairs, of which we take cotton as the type, or filaments of bast-tissue, represented by flax. No new plant hairs have been suggested which can compete in any way for spinning with those yielded by the species of

* *Useful Native Plants of Australia.*

gossypium, or cotton, but experiments more or less systematic and thorough are being carried on with regard to the improvement of the varieties of the species. Plant hairs for the stuffing of cushions and pillows need not be referred to in connection with this subject.

Countless sorts of plants have been suggested as sources of good bast-fibers for spinning and for cordage, and many of these make capital substitutes for those already in the factories, but the questions of cheapness of production, and of subsequent preparation for use, have thus far militated against success. There may be much difference between the profits promised by a laboratory experiment and those resulting from the same process conducted on a commercial scale. The existence of such difference has been the rock on which many enterprises seeking to introduce new fibers have been wrecked.

In dismissing this portion of our subject, it may be said that a process for separating fine fibers from undesirable structural elements, and from resin-like substances which accompany them, is a great desideratum. If this were supplied many new species would assume great prominence at once.

### VI.—TANNING MATERIALS.

What new tanning materials can be confidently sought for? In his *Useful Native Plants of Australia*, Mr. Maiden describes over thirty species of "Wattles" or Acacias, and about half as many Eucalypts, which have been examined for the amount of tanning material contained in the bark. In all, eighty-seven Australian species have been under examination. Besides this, much has been done looking in the same direction, at the suggestion and under the direction of Baron von Mueller, of Victoria. This serves to indicate how great is the interest in this subject and how wide is the field in our own country for the introduction of new tanning plants.

It seems highly probable however that artificial tanning substances will at no distant day replace the crude matters now employed.

### VII.—RESINS, ETC.

Resins, oils, gums, and medicines from the vegetable kingdom would next engage our attention if they did not seem rather too technical for this occasion and to possess an interest on the whole somewhat too limited, but an allied substance may serve to represent this class of products and indicate the drift of present research.

*India Rubber.**—Under this term are included numerous substances which possess a physical and chemical resemblance to each other. An Indian *Ficus*, the early source of supply, soon became inadequate to furnish the quantity used in the arts even when the manipulation of rubber was almost unknown. Later, supplies came from *Hevea* of

* J. R. Jackson, *Commercial Botany of the Nineteenth Century*.

Brazil, generally known as Para rubber, and from *Castilloa*, sometimes called Central American Rubber, and from *Manihot Glaziovii* Ceara rubber. Not only are these plants now successfully cultivated in experimental gardens in the tropics, but many other rubber-yielding species have been added to the list. The Landolphias are among the most promising of the whole: these are the African rubbers. Now in addition to these which are the chief source of supply, we have *Willughbeia*, from the Malayan Peninsula, *Leuconotis*, *Chilocarpus*, *Alstonia*, *Forsteronia*, and a species of a genus formerly known as *Urostigma*, but now united with *Ficus*. These names, which have little significance as they are here pronounced in passing, are given now merely to impress upon our minds the fact that the sources of a single commercial article may be exceedingly diverse. Under these circumstances search is being made not only for the best varieties of these species but for new species as well.

There are few excursions in the tropics which possess greater interest to a botanist who cares for the industrial aspects of plants than the walks through the gardens at Buitenzorg in Java and at Singapore. At both these stations the experimental gardens lie at some distance from the great gardens which the tourist is expected to visit, but the exertion well repays him for all discomfort. Under the almost vertical rays of the sun, are here gathered the rubber-yielding plants from different countries, all growing under conditions favorable for decisions as to their relative value. At Buitenzorg a well-equipped laboratory stands ready to answer practical questions as to quality and composition of their products, and year by year the search extends.

I mention this not as an isolated example of what is being accomplished in commercial botany, but as a fair illustration of the thoroughness with which the problems are being attacked. It should be further stated that at the garden in question assiduous students of the subject are eagerly welcomed and are provided with all needed appliances for carrying on technical, chemical, and pharmaceutical investigations. Therefore I am justified in saying that there is every reason for believing that in the very near future new sources of our most important products will be opened up and new areas placed under successful cultivation.

At this point attention must be called to a very modest and convenient handbook on the Commercial Botany of the Nineteenth Century by Mr. Jackson of the Botanical Museum attached to the Royal Gardens, Kew, which not only embodies a great amount of well-arranged information relative to the new useful plants, but is at the same time a record of the existing state of things in all these departments of activity.

### VIII.—FRAGRANT PLANTS.

Another illustration of our subject might be drawn from a class of plants which repays close study from a biological point of view, namely, those which yield perfumes.

In speaking of the future of our fragrant plants we must distinguish between those of commercial value and those of purely horticultural interest. The former will be less and less cultivated in proportion as synthetic chemistry by its manufacture of perfumes replaces the natural by the artificial products, for example, coumarin, vanillin, nerolin, heliotropin, and even oil of wintergreen.

But do not understand me as intimating that chemistry can ever furnish substitutes for living fragrant plants. Our gardens will always be sweetened by them, and the possibilities in this direction will continue to extend both by contributions from abroad and by improvement in our present cultivated varieties. Among the foreign acquisitions there are the fragrant species of *Andropogon*. Who would suspect that the tropical relatives of our sand-loving grasses are of high commercial value as sources of perfumery oils?

The utility to the plant of fragrance in the flower and the relation of this to cross-fertilization, are apparent to even a casual observer. But the fragrance of an aromatic leaf does not always give us the reason for its being.

It has been suggested for certain cases that the volatile oils escaping from the plants in question may, by absorption, exert a direct influence in mitigating the fierceness of action of the sun's rays. Other explanations have also been made, some of which are even more fanciful than the last.

When however one has seen that the aromatic plants of Australia are almost free from attacks of insects and fungi, and has learned to look on the impregnating substances in some cases as protective against predatory insects and small foes of all kinds, and in others as fungicidal, he is tempted to ask whether all the substances of marked odor which we find in certain groups of plants may not play a similar rôle.

It is a fact of great interest to the surgeon that in many plants there is associated with the fragrant principle a marked antiseptic or fungicidal quality; conspicuous examples of this are afforded by species of *Eucalyptus*, yielding eucalyptol, *Styrax*, yielding styrone, *Thymus* yielding thymol. It is interesting to note too that some of these most modern antiseptics were important constituents in the balsamic vulneraries of the earliest surgery.

### IX.—FLORISTS' PLANTS.

Florists' plants and the floral fashions of the future constitute an engaging subject which we can touch only lightly. It is reasonably clear that while the old favorite species will hold their ground in the guise

of improved varieties, the new introductions will come in the shape of plants with flowering branches which retain their blossoms for a somewhat long period, and especially those in which the flowers precede the leaves. In short the next real fashion in our gardens is probably to be the flowering shurb and flowering tree, like those which are such favorites in the country from which the Western world has gladly taken the gift of the chrysanthemum.*

Twice each year of late a reception has been held by the Emperor and Empress of Japan. The receptions are in autumn and in the spring. That in the autumn, popularly know as the Emperor's reception, has for its floral decorations the myriad forms of the national flower, the chrysanthemum; that which is given in spring, the Empress's reception, comes when the cherry blossoms are at their best. One has little idea of the wealth of beauty in masses of flowering shurbs and trees, until he has seen the floral displays in the Imperial Gardens and the Temple grounds in Tokio.

To Japan† and China also we are indebted for many of the choicest plants of our gardens, but the supply of species is by no means exhausted. By far the larger number of the desirable plants have already found their way into the hands of cultivators, but often under conditions which have restricted their dissemination through the flower-loving community. There are many which ought to be widely known, especially the fascinating dwarf shrubs and dwarf trees of the far East, which are sure to find sooner or later a warm welcome among us.

### X.—FORAGE PLANTS.

Next to the food plants for man, there is no single class of commercial plants of greater interest than the food-plants for flocks and herds. Forage plants, wild and cultivated, are among the most important and highly valued resources of vast areas. No single question is of more vital consequence to our farthest West and Southwest.

It so happens that the plants on which the pastoralist relies grow or are grown on soil of inferior value to the agriculturist. Even soil which is almost sterile may possess vegetation on which flocks and herds may graze, and further, these animals may thrive in districts where the vegetation appears at first sight too scanty or too forbidding even, to support life. There are immense districts in parts of the Australian continent where flocks are kept on plants so dry and desert-

* *The Flowers of Japan and the Art of Floral Arrangement.* By Josiah Conder. F. R. I. B. A., Architect to the Imperial Japanese Government. Yokohama, 1891. See also two other works by the same author: *Theory of Japanese Flower-arrangements*, and *Art of Landscape-gardening in Japan.* (1886.)

† *Ibidem.*

like that an inexperienced person would pass them by as not fit for his sheep; and yet, as Mr. Samuel Dixon* has well shown, these plants are of high nutritive value and are attractive to flocks.

Relegating to the foot-notes, brief descriptions of a few of the fodder plants suggested for use in dry districts, I shall now mention the salt bushes of various sorts, and the allied desert plants of Australia as worth a careful trial on some of our very dry regions in the farthest west. There are numerous other excellent fodder plants adapted to dry but not parched areas which can be brought in from the corresponding districts of the southern hemisphere and from the East.

At an earlier stage of this address,† I have had occasion to refer to Baron Von Mueller, whose efforts looking towards the introduction of useful plants into Australasia have been aided largely by his convenient treatise on economic plants. It may be said in connection with the fodder plants, especially, that much which the Baron has written can be applied *mutatis mutandis* to parts of our own country.

The important subject of introducing fodder plants has been purposely reserved to the last because it permits us to examine a practical point of great interest. This is the caution which it is thought necessary to exercise when a species is transferred by our own choice from one country to another. I say, by our choice, for whether we wish it or not certain plants will introduce themselves. In these days of frequent and intimate inter-communication between different countries the exclusion of foreign plants is simply impossible. Our common weeds are striking illustrations of the readiness with which plants of one country

* Mr. Samuel Dixon's list is in vol. VIII (for 1884–85) of the *Transactions and Proceedings and Report of the Royal Society of South Australia*. Adelaide, G. Robertson, 1886. *Bursaria spinosa*, "a good stand-by," after the grasses dry up. *Pomaderris racemosa*, "stands stocking well." *Pittosporum phyllaeroides*, "sheep exceedingly partial to its foliage." *Casuarina quadrivalvis*, "tenderness of fiber, wool would be represented by it in our finer wool districts." *Acacias*, The Wattles; "value as an astringent, very great," being curative of a malady often caused by eating frozen grass. *Acacia aneura* (mulga); "must be very nutritious to all animals eating it." This is the plant which is such a terror to the stockmen who have to ride through the "scrub." *Cassia*, some of the species with good pods and leaves for sheep. The foregoing are found in districts which are not wholly arid. The following are more properly "dry" plants. *Sida petrophila*, "as much liked by sheep as by marsupials." *Dodonaea viscosa*, Native Hop-bush; "likes warm, red, sandy ground." *Lycium australe*, "drought never seems to affect it." *Kochia aphylla:* "All kinds of stock are often largely dependent on it during protracted droughts." *Rhagodia parabolica:* "Produces a good deal of foliage." *Atriplex vesicaria:* "Can be readily grown wherever the climate is not too wet." I have transferred only those which Mr. Dixon thinks most worthy of trial. Compare also Dr. Vasey's valuable studies of the plants of our dry lands, especially Grasses and forage plants (1878), Grasses of the arid districts of Kansas, Nebraska, and Colorado (1886), Grasses of the South (1887).

† See foot-note at pages 617, 618.

make for themselves a home in another.* All but two of the prominent weeds of the Eastern States are foreign intruders.

There are all grades of persistence in these immigrants. Near the ballast grounds of every harbor, or the fields close by woolen and paper mills where foreign stock is used, you will observe many foreign plants which have been introduced by seed. For many of these you will search in vain a second year. A few others persist for a year or two longer, but with uncertain tenure of the land which they have invaded; others still have come to stay. But happily some of the intruders which seem at first to gain a firm foothold, lose their ground after a while. We have a conspicuous example of this in a hawk-weed, which was very threatening in New England two years ago, but is now relaxing its hold.

Another illustration is afforded by a water plant which we have given to the Old World. This plant, called in our botanies *Anacharis*, or *Elodea*, is so far as I am aware not troublesome in our ponds and water ways, but when it was carried to England, perhaps as a plant for the aquarium, it was thrown into streams and rivers with a free hand. It spread with remarkable rapidity and became such an unmitigated nuisance that it was called a curse. Efforts to extirpate it merely increased its rate of growth. Its days of mischief are however nearly over, or seem to be drawing to a close, at least so Mr. Lynch, of the Botanic Garden in Cambridge, England, and others of my informants think. The history of the plant shows that even under conditions which so far as we can see, are identical with those under which the plant grew in its home, it may for a time take a fresh lease of life and thrive with an undreamed-of energy.

What did *Anacharis* find in the waters of England and the continent that it did not have at home, and why should its energy begin to wane now?

In Australasia one of the most striking of these intruders is sweetbriar. Introduced as a hedge plant it has run over certain lands like a weed, and disputes every acre of some arable plats. From the facility with which it is propagated, it is almost ineradicable. There is something astounding in the manner in which it gains and holds its ground. Gorse and brambles and thistles are troublesome in some localities, and they prove much less easy to control than in Europe. The effect produced on the mind of the colonist by these intruding pests is everywhere the same. Whenever in an examination of the plants likely to be worthy of trial in our American dry lands the subject was mentioned by me to Australians, I was always enjoined to be

* The weeds of German gardens and agricultural lands are mostly from Mediterranean regions, but the invasions in the uncultivated districts are chiefly from America (such as *Oenothera*, *Mimulus*, *Rudbeckia*). Handbuch der *Pflanzengeographie*, von Dr. Oscar Drude (Stuttgart), 1890, p. 97.

cautious as to what plants I might suggest for introduction from their country into our own. My good friends insisted that it was bad enough to have as pests the plants which come in without our planning or choice, and this caution seems to me one which should not be forgotten.

It would take us too far from our path to inquire what can be the possible reasons for such increase of vigor and fertility in plants which are transferred to a new home. We should have to examine all the suggestions which have been made, such as fresh soil, new skies, more efficient animal friends or less destructive enemies. We should be obliged also to see whether the possible wearing out of the energy of some of these plants after a time might not be attributable to the decadence of vigor through uninterrupted bud propagation, and we should have to allude to many other questions allied to these. But for this time fails.

Lack of time also renders it impossible to deal with the questions which attach themselves to our main question, especially as to the limits of effect which cultivation may produce. We can not touch the problem of inheritance of acquired peculiarities, or the manner in which cultivation predisposes the plant to innumerable modifications. Two of these modifications may be mentioned in passing, because they serve to exemplify the practical character of our subject.

Cultivation brings about in plants very curious morphological changes. For example, in the case of a well-known vegetable, the number of metamorphosed type leaves forming the ovary is two, and yet under cultivation the number increases irregularly until the full number of units in the type of the flower is reached. Prof. Bailey, of Cornell, has called attention to some further interesting changes in the tomato, but the one mentioned suffices to illustrate the direction of variation which plants under cultivation are apt to take. Monstrosities are very apt to occur in cultivated plants, and under certain conditions may be perpetuated in succeeding generations, thus widening the field from which utilizable plants may be taken.

Another case of change produced by cultivation is likewise as yet wholly unexplained, although much studied, namely, the mutual interaction of scion and stock in grafting, budding, and the like. It is probable that a further investigation of this subject may yet throw light on new possibilities in plants.

We have now arrived at the most practical question of all, namely, In what way can the range of commercial botany be extended? In what manner or by what means can the introduction of new species be hastened?

It is possible that some of you are aware of the great amount of unco-ordinated work which has been done and is now in hand in the direction of bringing in new plants.

The competition between the importers of new plants is so great both in the Old World and the New that a very large proportion of the species which would naturally commend themselves for the use of florists, for the adornment of greenhouses, or for commercial ends, have been at one time or another brought before the public, or are being accumulated in stock. The same is true, although to a less extent, with regard to useful vegetables and fruit. Hardly one of those which we can suggest as desirable for trial has not already been investigated in Europe or this country and reported on. The pages of our chemical, pharmaceutical, medical, horticultural, agricultural, and trade journals, especially those of high grade, contain a wealth of material of this character.

But what is needed is this, that the promising plants should be systematically investigated under exhaustive conditions. It is not enough that an enthusiast here or an amateur there should give a plant a trial under imperfectly understood conditions and then report success or failure. The work should be thorough and every question answered categorically, so that we might be placed in possession of all the facts relative to the object experimented upon. But such an undertaking requires the co-operation of many different agencies. I shall venture to mention some of these.

In the first place, botanic gardens amply endowed for research. The Arnold Arboretum, the Shaw Garden, and the Washington Experimental Garden are American illustrations of what is needed for this purpose. University gardens have their place in instruction, but can not wisely undertake this kind of work.

In the second place, museums and laboratories of economic botany. Much good work in this direction has been done in this country by the National Museum and by the department in charge* of the investigation of new plants. We need institutions like those at Kew in England, and at Buitenzorg in Java, which keep in close touch with all the world. The founding of an establishment on a scale of magnitude commensurate with the greatness and needs of our country is an undertaking which waits for some one of our wealthy men.

In the third place, experimental stations. These may, within the proper limits of their sphere of action, extend the study of plants beyond the established varieties to the species, and beyond the species to equivalent species in other genera. It is a matter of regret that so much of the energy displayed in these stations in this country, and we may say abroad, has not been more economically directed.

Great economy of energy must result from the recent change by which co-ordination of action is assured. The influence which the stations must exert on the welfare of our country and the development of its resources is incalculable.

* The list of economic plants published by the Department in Washington is remarkably full, and is in every way creditable to those in charge.

In the last place, but by no means least, the co-operation of all who are interested in scientific matters, through their observation of isolated and associated phenomena connected with plants of supposed utility, and by the cultivation of such plants by private individuals, unconnected with any State, governmental, or academic institutions.

By these agencies, wisely directed and energetically employed, the domains of commercial and industrial botany will be enlarged. To some of the possible results in these domains I have endeavored to call your attention.

## THE EVOLUTION OF COMMERCE.*

By Gardiner G. Hubbard.

For over three thousand years the great highway for commerce has been from India by the Persian Gulf and the Euphrates or by the Red Sea to the Mediterranean, and thence through the Mediterranean by Gibraltar to western and northern Europe, and in our day thence to America.

Along this route cities and nations have sprung up, increased in wealth and power, and passed away, giving place to other cities and nations further westward. These nations have been great carriers and distributors of minerals and goods, as well as capitalists and bankers, or carriers, bankers, and manufacturers; in either case controlling the commerce of the world. This control has never for any long period been held by the same race, but has passed from one nation to another, always from the east toward the west.

The earliest highway of commerce was from India through the Persian Gulf, up the Euphrates to the Mediterranean; and carpets and precious stones were then as now carried over this route. Explorations and surveys for a railroad have been recently made along this "our future highway to India." Caravans brought spices from Arabia and rich stuffs from Babylon and Nineveh to the shore of the Red Sea. Solomon made a navy of ships and Hiram sent in the navy his "Servants, shipmen that had knowledge of the sea, and they brought gold from Ophir, great plenty of almug trees, and precious stones."

Tyre and Sidon founded colonies on the shores of the Mediterranean, enslaving the Spaniards and compelling them to work the mines of gold and silver already opened in Spain. Their ships sailed through the Mediterranean, by the Pillars of Hercules, into the Atlantic Ocean, turning northward to England for tin and copper and on into the Baltic sea for furs and amber, turning southward along the western coast of Africa, passing certainly 2,000 miles to the equator, and probably rounding the Cape of Good Hope into the Indian Ocean. Products from the west were brought in ships to Tyre and Sidon and exchanged

* Presidential address to the National Geographic Society, January 15, 1892. (From *The National Geographic Magazine*, March 26, 1892: vol. IV, pp. 1–18).

for the goods of the east, their merchants making profits on each transaction both as merchants and as carriers. Tyre and Sidon became wealthy, luxurious, and effeminate. Some of their citizens saw in Africa a richer soil and a better situation for a large city, and founded Carthage. The Carthagenians inherited the trade of Tyre and Sidon, and in addition opened highways to Egypt and into the interior of Africa, bartering their wares in Egypt for corn and grain, and in Africa for ivory, gems, and slaves. They planted colonies in Africa and Sicily, and for a time were successful rivals of Greece and Rome.

The rule of the ocean transferred from Asia to Africa remained there but a short time, for the day of Europe came with the rise of Greece and Rome.

The Greeks founded colonies in Asia Minor, Sicily, and Italy. The ruins of great cities with Grecian temples and amphitheaters are found at Girgenti and Syracuse in Sicily, at Pæstum and other places in Italy. Under Pyrrhus, their armies were defeated by the Romans and her colonies captured. Deprived of these, her power rapidly declined and she became a Roman province.

*Rome.*—Rome founded few colonies, but she conquered the nations of Asia, Africa, and Europe, and brought under her sway cities, kingdoms, and empires. She boasted of 500 cities in her Asiatic province that had been founded or enlarged and beautified by the Cæsars. One hundred and twenty vessels each year brought the goods of India from the delta of the Ganges, and large fleets from Egypt came laden with corn and grain. She imported from every country, but exported little, paying for her imports by taxes levied on her colonists.

Rome was the first power to incorporate conquered states into her dominion and extend citizenship to all the people in her Empire, so that Paul could say in truth, "I am a Roman citizen and to Cæsar I appeal." So salutary and beneficial was her rule that under it these countries prospered more than under their own rulers. What Rome seized with strong hand she defended, and in return for taxation gave protection. She has no more enduring monument than her roads, the remains of which are now found in every country of Europe. Though built as military and post roads, they were used largely for commerce. All started from the golden mile-stone in the forum; one ran over the Brenner pass northeastward to the Baltic Sea, another followed the northwestern coast of the Mediterranean to Spain and southern France, another crossed the Alps and extended through France to the British channel and through England to Scotland, where the Romans built a wall, ruins of which now bear witness to its strength. Another way went southward to Naples and Brindisi, and another led eastward to Macedonia and Greece. As these were the only roads in all these countries, it was truly said, "All ways lead to Rome;" and over them the messenger of Cæsar travelled more rapidly than the mail-carrier of our fathers on our mail routes.

*Venice and Genoa.*—After 500 years of empire Rome fell, and the dark ages followed. From A. D. 400 to A. D. 800 commerce and trade died out. The only vessels on the Mediterranean and Baltic were piratical crafts; Jerusalem and the Holy Land were captured by the Turks; the Crusades began, forerunners of a higher civilization and more extended commerce. Thousands and tens of thousands of people from all parts of Europe and all ranks of life, bearing the pilgrim's badge—the blood-red cross—journeyed toward the Holy Land, first in vast crowds led by Peter the Hermit, then in great armies led by kings and generals. For years this movement continued. Venice and Genoa furnished ships to carry the armies of France from Italy to the Holy Land. The Venetians were shrewd merchants and drove hard bargains, stipulating for cessions of land at the best commercial points and adequate compensation for their services. After the failure of each Crusade they brought back remnants of the troops and pilgrims, and with them the products of Asia Minor, and books and art treasures from Greece. These were distributed all over Italy, and led to the renaissance of the thirteenth and fourteenth centuries.

The trade with the east brought power and wealth to Venice and Genoa. They founded colonies on the Black Sea, in Asia Minor, and on the Asiatic coast. Venice alone had 3,000 vessels. Their commerce was not confined to the borders of the Mediterranean, for the goods of the Orient were distributed by the way of Augsburg and Nuremberg to the interior of Germany and to the towns of the Hanseatic confederation. Thus commerce was opened with the interior of Europe.

By the failure of the Crusades the power of the Turks, which had been for some time checked, grew and increased. They conquered the holy places of the earth, Asia Minor and Syria, and finally, crossing into Europe, gained Constantinople. The colonies of Venice and Genoa were captured; their fleets disappeared from the Mediterranean. In western Europe the Spaniards under Ferdinand and Isabella conquered the Moors, who for many ages had occupied the larger portion of Spain; and as the Crescent appeared in eastern Europe the Cross triumphed in the west.

*Spain and Portugal.*—Then a new power appeared upon the stage. Spain and Portugal entered upon an era of exploration and discovery in regions unknown to Venice and Genoa. Commerce, which in the middle ages had been confined to the Mediterranean Sea, was now extended to the countries on the Atlantic Ocean, and the Cape Verde Islands, Madeira, and the Canaries were discovered. In one generation (between 1470 and 1500 A. D.) more and greater discoveries were made than in any other period of the world's history. The Portuguese sailed along the eastern coast of Africa and rounded the Cape of Good Hope; Vasco de Gama crossed the Indian Ocean to India; Columbus

sailed westward to find the Orient and discovered a new world; Magellan circum-navigated the globe; Balboa crossed the Isthmus of Panama, and was the first to see, on the same day, the sun rise out of the Atlantic and set in the Pacific; and soon the eastern and western coasts of America were explored from Newfoundland to Cape Horn and from Cape Horn to Panama.

Both Portugal and Spain claimed all the New World, and as they could not agree upon a division of territory they referred the matter to the Pope, who divided the New World between them. The Atlantic became the great highway for commerce, while the Mediterranean was deserted, and Venice and Genoa existed only in the past.

The commerce of Portugal was co-extensive with her dominion, which extended from Japan and the Spice Islands and India to the Red Sea, thence to the Cape of Good Hope; and with their possessions on the eastern and western shores of the Atlantic and in Africa and Brazil completed their maritime empire, the most extensive the world has ever seen. Then a single fleet of one hundred and fifty to two hundred and fifty caracks sailed from the port of Goa to Lisbon; now there sails but one vessel a year from all India.

From Spain ships sailed both to the Caribbean Sea and to Cape Horn and thence to Chile and Peru, or directly northwestward from Cape Horn to the Philippine Islands. Spain conquered Mexico, Central America, and all South America except Brazil. The gold and silver of Peru and Chile, and the goods of the Orient, were brought to Spain and Portugal. As their wealth and power increased the spirit of exploration decreased, and for nearly two hundred years the Spanish ships sailed in a fixed course by the same lanes, exploring the ocean neither toward the north nor the south, leaving undiscovered the great continent of Australia and numerous groups of islands.

The Spanish and Portuguese leaders were cavaliers, who despised all commerce excepting in gold and silver, all kinds of manufactures, all manual labor, and the cultivation of the ground. They came not to colonize, but to satisfy by the labor of the enslaved aborigines their thirst for gold and silver. The whole political power was retained by the King of Spain and administered by Spaniards. While the silver and gold of America and the wealth of the Indies poured into the treasuries of Spain they wanted nothing more. Like ancient Rome, they took all the wealth of the conquered countries, making no return; but they did not, like Rome, give wise and equitable laws and a stable government to the countries they conquered.

*The Netherlands.*—The inhabitants of the Netherlands were manufacturers, and supplied the markets of Spain and Portugal and their colonies, thus reaping as large profits from their trade with these countries as the Spanish and Portuguese from the mines of gold and silver.

No part of Europe, says Motley, seemed so unlikely to become the home of a great nation as the low country on the northwestern coast

of the continent, where the great rivers, the Rhine and Scheldt, emptied into the North Sea, and where it was hard to tell whether it was land or water. In this region, outcast of ocean and earth, a little nation wrested from both domains their richest treasures.

The commerce of the Hanseatic Towns, which had depended for their trade on Venice and Genoa, became less and less as the glory of those cities waned. Antwerp, with its deep and convenient rivers, stretched its arms to the ocean and caught the golden harvest as it fell from its sisters' grasp. No city except Paris surpassed it in population; none approached it in splendor. It became the commercial center and banker of Europe; 5,000 merchants daily assembled on its exchange; 2,500 vessels were often seen at once in its harbor, and 500 daily made their entrance into it. The manufactures of Flanders and the Netherlands had been noted for many generations, and now vastly increased, were distributed all over the world. The Netherlands, though the smallest, became the wealthiest nation of Europe. Then came the long-continued war with Spain, ending in the siege and fall of Antwerp, and in the imposition of such taxation as no other country had ever endured. As Antwerp had grown on the ruins of the Hanseatic Towns, so her fall became England's gain.

*France and England.*—In America, north of Mexico, neither silver nor gold had been found to tempt the Spanish and Portuguese. The larger portion of the northern Atlantic coast was one long sand beach, broken by great estuaries and the mouths of great rivers; the rest was rocky and rugged, the temperature generally cold, the land unfertile and barren. For these reasons North America was left to the French and English. The French claimed Canada and the whole of the territory of the United States save a narrow strip of land on the Atlantic coast. The French population was small, and was made up principally of fur-traders and half-breeds; Great Britain held New England, Virginia, and the Carolinas.

After the first fever of religious colonization had passed, about the commencement of the eighteenth century, there was scarcely any emigration from England to America and but little trade between the two countries. The population of North America was small, its commerce less, with little profit to the European merchants. The country possessed no peculiar advantages for the production of articles of value in foreign markets; there was nothing, therefore, to invite immigration or commerce.

The chief inducement to the English to navigate the Atlantic was the hope of capturing the treasure-laden Spanish galleons and the rich Spanish cities.

Sir Francis Drake, Sir Walter Raleigh, and other navigators, aided by Queen Elizabeth, with bands of buccaneers, refugees from all countries, though mostly Englishmen, explored the recesses of the Caribbean Sea, crossed the Isthmus of Panama, and launched their little

vessels on the Pacific. In 15 years they captured 545 treasure ships, sacked many towns, trained the English seaman, and laid the foundation for the navy of Great Britain.

The growth of English commerce was slower than that of Spain, Portugal, or Holland, and it was not until the middle of the eighteenth century, or 250 years after the discovery of America, that she entered upon that career which gave her the control of the ocean. Her commerce was built up by protective laws, founded on the navigation act of 1651, which prohibited foreign vessels from carrying to or from England the commerce of any country but its own. These laws were universally regarded as among the chief causes and most important bulwarks of the prosperity of Great Britain, and they were continued until English ships controlled the carrying trade of the world, and were not finally repealed until 1854.

The mechanical devices of Watt, Arkwright, and other great inventors gave to England that supremacy in manufactures which she has ever since retained. The French revolution, a little later, aroused the fear of the statesmen, merchants, and capitalists of England that the energy of the new Republic would be as omnipotent in mercantile affairs as on the field of battle. They believed that France might regain the colonies and with them the commerce she had lost, and therefore England declared war against Napoleon, which was carried on almost continuously from 1793 to 1815. The shipping of the Continent disappeared or was captured by the fleets of England; the colonies, and with them the commerce, of Spain and Portugal, Holland and France, passed to England; and though she is still burdened with the debt then created, she has never lost the commerce and carrying trade she then obtained.

The population of the colonies of Great Britain is about one-sixth of the entire population of the globe, and their territory comprises eighty per cent of the available temperate regions of the earth belonging to the Anglo-Saxon race.

The commerce of England has given wealth to her bankers and merchants, and employment to her artisans, ship-builders, iron-workers, miners, and manufacturers. Her exports of produce and manufactures have increased 500 per cent in fifty years, or from $356,000,000 in 1840 to $1,577,000,000 in 1890, and are carried by her ships to every quarter of the globe. Though dependent on America for her food supplies, these are moved in British ships. The commerce of the world pays tribute to the bankers of London and makes that city the money center of the world. Her best market is India, and from India comes her largest imports; next to this, those from the United States.

*India.*—Egypt, Nineveh, and Babylon in prehistoric times, Tyre and Sidon and Greece under Alexander, Carthage and Rome under the Cæsars, Venice and Genoa in the middle ages, Portugal and Holland, and lastly England, have drawn great stores of wealth from India.

From India science and literature were handed on to Europe, and from India has come the religion of more than half of the human race. For India the Spanish sailed westward; for India the Portuguese sailed eastward. Portugal was the first to reach the goal and obtain the prize. Greater riches have been drawn from India than from the gold and silver mines of America; since for all ages it has been the storehouse from which treasures were derived. Portugal held India from about 1500 to 1600. Ships brought the silks and precious stones of India to Lisbon, where they were sold to the Dutch and distributed by them through Europe. Spain conquered Portugal, and to avenge herself on Holland excluded her merchants from Lisbon. They then sailed directly for India, dispossessed the Portuguese, and the commerce of India was for the next hundred years controlled by Holland.

Then for a short time India was divided between France and England, but under Lord Clive and Warren Hastings the possessions of France passed to the East India Company, and when their charter expired it was made a province of the Crown, and the Queen of England became Empress of India.

Unlike Rome and Spain in their dealings with conquered nations, England gives a fair exchange for all she takes, and rules in India for India, giving a more stable and equitable government than India ever before enjoyed.

To-day Tyre, Sidon, and Carthage are known only by their ruins; the glory of Greece and Rome, of Venice and Genoa, has passed; the power of Spain and Portugal has waned, while India is developing a social, moral, and political prosperity, with wealth and commerce unknown in any former period of her history.

*Suez Canal.*—Much of the trade of India in ancient times passed through a canal connecting the Red Sea with the Mediterranean, the remains of which still exist, and efforts to re-open it have been made at different times by Egypt without success. In 1856 De Lesseps obtained concessions from the Khedive for the Suez Canal, and commenced the work under the directions of the best engineers of Europe. De Lesseps applied to English capitalists for help, but they were deterred by Lord Palmerston, who said he "would oppose the work to the very end." Mr. Stevenson, the engineer, supported Lord Palmerston, declaring that "the scheme was impracticable, except at an expense too great to warrant any expectation of returns." The Emperor of France lent his name to the company, and large sums of money were raised in France; but the canal was constructed mainly by the money and laborers of Egypt. It was opened in 1869, and immediately English steamers began to sail through the canal, and the route around the Cape of Good Hope was almost abandoned. Other flags soon followed, and the commerce with India and the East, so long lost to Venice and the ports of the Mediterranean, was revived.

In 1875, Lord Beaconsfield purchased for England a controlling interest in the Suez Canal, and England now rules both Egypt and the canal. The vessels of all the maritime nations of the world are constantly passing through the canal, with the single exception of those of the United States.

*Colonies.*—The commerce of the great nations of the world has been principally with their colonies or dependencies, and from this commerce they have derived their wealth. The mother country in return for its real or nominal protection, and for its own aggrandizement, has restricted the commerce of her colonies.

The European nations adopted four classes of restrictions:

(1) Restricting the exportation of goods from the colony except to the mother country.

(2) Restricting the importation of goods from foreign countries into the colonies.

(3) Restricting the exportation or importation of goods excepting in ships of the mother country.

(4) Restricting the manufacture of their own raw products by the colonies. So strong was this feeling in England that even Lord Chatham declared in Parliament, "The British colonies of North America have no right to manufacture even a nail or a horseshoe."

Most of these restrictions have been removed, though the result still remains.

The Phœnicians, Carthagenians, and Greeks had colonies on the Mediterranean. The Romans conquered and held as subjects nations and empires. Venice and Genoa had colonies on the Black and Mediterranean seas. Spain and Portugal held as dependencies all Central America, South America, Africa, India, and the islands of the Pacific. The Dutch Republic and France planted colonies in India and America. England has colonies in every part of the world, and on her dominion the sun never sets.

Germany, France, Portugal, and Russia, appreciating the necessity of colonies for the extension of their commerce and for opening new markets for their manufactures, are planting colonies—France in Cochin China, Germany on the eastern and western coasts of Africa and the islands of the Pacific. Portugal, aroused to a new life, is determined to hold her remaining possessions in Africa; Russia is steadily adding to her dominions in Asia, and her railway from the Caspian Sea to Samarcand has opened in western and a part of central Asia a market for her manufactures and commerce hitherto supplied by Great Britain.

*United States.*—The United States is the only nation that has become great without colonies and without foreign commerce and shipping. Its vast extent of territory, where the east and west, the north and south are separated more widely than the colonies of Tyre and Sidon or of Carthage and Rome from the mother countries; the great variety

of climate, the fertile soil, its varied occupations and manufactures, and a widely distributed population have created an enormous inland commerce and given that trade and wealth which other countries find in commerce and exchange with their colonies. Our population, wealth, internal commerce, exports and imports have increased at a more rapid rate than those of any other nation in a similar period. This is not due in any great degree to immigration, for our population has increased in no greater ratio since this immigration commenced than before, and experts believe that it would have been as large and more homogeneous without immigration. We had at one time a large foreign commerce, and our merchants were the first to establish direct trade with China and the East Indies; the Stars and Stripes were seen floating on every sea and flying in every harbor, and for years we were the second maritime nation of the world.

The commerce of the world passed from wooden sailing ships to side-wheel steamers, to iron and then to steel propellers; England was a worker in iron and machinery of every kind; we were not. The civil war came and hastened the day which was sure to come. Our shipping faded away faster than it had arisen, while that of Great Britain increased as rapidly as ours decreased. This was not owing to a decrease of our foreign trade, for during the last twenty years our exports and imports have increased more than twice as rapidly as those of Great Britain.* Eighty-seven per cent of these exports and imports are carried in British ships, consigned to English houses which have been established in every large port in the world, and the proceeds are usually remitted to the London banker.

Fortunately, our flag never disappeared from our inland waters and from our coasting trade, for foreigners are excluded from the coasting trade, even where the ports are 15,000 miles apart by water.

The substitution of steamers for sailing ships and of steel for wooden propellers, which took place from ten to twenty years ago on the ocean, is now going rapidly on upon our lakes. Where in 1886 there were but 6 steel propellers, now there are 68, and of 2,225 vessels on the northern lakes, 1,153 are steamers, 902 are sailing vessels. The action of Congress in providing for the construction and equipment of war vessels by competition has led our ship-builders within the last eight years to establish ship-yards and machine shops where the largest ships can be built, and we are now building as large and fast vessels of war as England. Our ship-builders claim that they can construct ships equal in carrying capacity, speed, and strength to those of Great Britain, and at no greater cost, though they can not be run so cheaply because our sailors are better housed, fed, and paid than those of other nations.

* The exports of the United States have increased 112 per cent, the exports and imports 92 per cent; the exports of Great Britain 35 per cent, her exports and imports 37 per cent.

The day will surely come when commerce will make her last movement westward, when America, lying between Europe and Asia, with her boundless mineral and agricultural resources, her manufacturing facilities, her extended sea-coasts, will be the foremost nation and New York the commercial capital of the world.

*Nicaragua Canal.*—From New York to San Francisco by land is about 3,000 miles, by water it is about 15,000 miles, yet, notwithstanding the greater distance, freight is constantly sent by water. From San Francisco it is about the same distance by water to either New York or London. If a water-way could be opened across the Isthmus of Panama from one ocean to the other, the distance from New York to San Francisco would be diminished more than one-half, and San Francisco would be over 2,000 miles nearer New York than London. The first proposition for canals connecting the two oceans was made in 1550, suggesting two routes, by Panama and Nicaragua; and explorations and surveys of both have been frequently made, and various attempts made for their construction.

The success of the Suez Canal induced M. de Lesseps to undertake the connection of the two oceans by the construction of the Panama Canal, believing that the tonnage passing through it would equal that of the Suez Canal. This work has not been successful; the canal remains unfinished, with no prospects of completion.

Several hundred miles north of Panama is the lowest continental divide; 148 feet above tide water on the Pacific slope of this divide is Lake Nicaragua, connected by the river San Juan with the Atlantic; up this river and through this lake, some thirty years ago, was one of the regular ways of inter-communication, both for freight and passengers, between New York and California.

The Maritime Canal Company and the Canal Construction Company, organized by Americans, have obtained concessions from Nicaragua, and have made surveys for canal, slack-water, and lake navigation from Greytown on the Atlantic through Lake Nicaragua to Brito on the Pacific, a distance of 170 miles. A harbor has been opened at Greytown and considerable work performed on the canal. The Panama route had the great advantage of an open channel from ocean to ocean, whereas the Nicaragua route requires several locks to cross the divide; but Brito is some 600 or 700 miles nearer California than Panama, a saving in distance that will compensate for the delay in locking. The opening of this canal will be the greatest benefit that could be conferred upon our commerce and shipping.

Freights by water between New York and California are now so high that a large portion goes by railroad. The effect that this canal should produce will be evident if we consider the great difference in expense between land and water carriage. Rail rates between New York and Chicago are a trifle over 6 mills per ton per mile, while the

ocean rates on grain to Liverpool in 1888 were about half a mill per ton per mile; and 1 mill per ton per mile, or $3 per ton from New York to Liverpool is said to be a fair rate, while the all-rail rate between New York and San Francisco averages from $40 to $80 per ton, according to the class to which the freight belongs. It takes from seven to ten days to go from New York to Liverpool, nearly twice as long as from New York to San Francisco by rail, thirty days by Panama, and one hundred and twenty days by the all-water route around Cape Horn.

The opening of this canal will therefore reduce the freight on goods between the East and West at least three-fourths and possibly more. It will give us a free, easy, and cheap communication by water between the Eastern and Western States; our commerce will be built up, and the wealth and commerce of the Atlantic coast and the population of the states on the Pacific coast will be increased in a wonderful manner.

The opening of this route will give a demand for large steamships, and when we have such ships large shipyards and machine-shops will spring up, and these alone are wanted to enable us to build and run ships on the Atlantic Ocean in competition with Great Britain. Then the prediction of Mr. Cramp will be fulfilled, that Englishmen will be asking one another, "Can we build ships as economically as they do in the United States?"

*Modes of conveyance.*—The earliest transportation of merchandise was by caravans. The first caravan of which we have any certain account was that of the Ishmaelites and Moabites, who, while they were traveling from Gilead, with their camels bearing spices, balm, and myrrh, to Egypt, bought Joseph of his brethren and sold him as a slave to Potiphar. These caravans were formed of merchants banded together for protection under a guide and leader, sometimes numbering several hundred, with one thousand camels in a caravan. They travelled from 17 to 20 miles a day, but only in the spring and autumn months. At night they stopped at caravansaries, where free lodging was furnished to men and beasts. In Turkistan and Arabia all trade and travel was by similar caravans until the railroad was opened across the desert, by Merv and the Oxus, to Samarcand.

Navigation was first by boat, and ages afterward by vessels. The earliest vessels of which we have any account were employed in carrying cattle down the Nile, and were propelled by sails and rowers. The vessels, at first small and with a few rowers, were slowly increased in size and number of rowers until three, four, and even five banks of oars, one over the other, were used. They were often from 150 to 175 feet long and from 18 to 26 feet in breadth, drawing from 10 to 12 feet of water, and sometimes carrying two hundred rowers and several hundred men. All these ships were without decks, whether sailing on the Mediterranean or Atlantic. They sailed by day, putting into harbor at night, and never losing sight of land unless driven by stress of weather. At

first they sailed only with the wind, but by slow degrees they learned to tack; then decks were built over the stern and prow, leaving the midships exposed to the high seas. This class of vessels, sometimes with banks of oars, continued until the middle of the last century. In the early part of the fifteenth century smaller but stronger vessels of better material were built for the voyages of discovery undertaken by the Portuguese. At this time, also, the mariner's compass was brought into general use, having been introduced from Arabia; eighty years later it found its way to England. Two of the vessels of Columbus were decked only at the prow and stern, and the three were manned by 120 men.

The armada of Queen Elizabeth was formed of merchant vessels fitted up as men-of-war, and not until the time of Charles I were there any regular ships of war in England or, probably, in other countries.

Commerce was usually carried on by companies, with rules regulating the quantity of goods to be exported, so that the market should not be over-stocked and unremunerative prices obtained. Sometimes the merchant was owner of the vessel, who adventured with his cargo and sailed in his own ship. The ships were constructed with little reference to speed, sailing 40 or 50 miles a day.*

The steam engine came into use near the middle of the eighteenth century in England, and two generations passed before it was used on vessels. The first steamboat ran on the Hudson in 1807, in England in 1812. Then another generation passed before the ocean was crossed by the *Sirius* and *Great Western*, in 1833. These ships sailed from 7 to 8 knots an hour. Ten years later iron ships were built; then came the propeller, the invention of Ericsson, followed by vessels built of steel. and lastly the *City of Paris* and *Majestic*, carrying 1,500 tons of freight and sailing 500 knots a day, or 20 knots an hour.

Until the present century all commerce between remote points was by water, excepting in the Roman Empire. After the downfall of Rome there was neither commerce nor travel and no use for roads, the cost of transportation even for a short distance exceeding the value of the goods.

The railroad was introduced about the same time into England and America, and was rapidly extended into every country. The steam engine on land and water has revolutionized the methods of transportation and created a new commerce. "The movement of goods in a year on all the through routes of the world did not then equal the movement on a single one of our trunk lines of railroad for the same period." Formerly it cost $10 to move a ton of freight 100 miles; now it can be moved 1,300 miles for the same sum. The grain and corn from our Western lands, then not worth the transportation to the seacoast, are now sold in London, and our prairies yield to the Western

*The breadth was about one-fourth the length, and not until within forty years were the proportions of one-tenth or one-twelfth of the breadth obtained.

farmer greater profit than the grain lands of England yield to the farmer there. The land commerce created by steam probably exceeds to-day the commerce carried on the water.

The cost of moving freight by railroads varies greatly in different parts of the United States and in different countries. The highest cost west of the Rocky Mountains is two and a quarter times more than in some of our Middle States. The average freight receipts per ton per mile in this country is $0.922, which is less than those of any other country, although the Belgian and Russian rates are not much higher. In England the rates are from 50 to 70 per cent higher than in America, and in the other countries of Europe higher than in England.

In England and America the railroads are operated by private companies in competition.

In France railroads are operated by private companies regulated by law, the country being divided among different lines of road. Lines are constructed by private companies and run at rates fixed by the Government.

In Belgium and Germany the principal roads are owned and operated by the Government.

Our system has yielded the best results to the people.

The commerce which was in olden times transported only 20 or 25 miles a day is now moved 500 miles a day by water and 800 miles by land. Correspondence, then carried no faster than freight, is now borne by telegraph to the farthest ends of the world.

All these changes have taken place within a single generation; for our fathers could not travel any faster than Alexander or Cæsar. Steamships, railroads, and telegraphs within that time have transformed all commercial transactions and the methods of commercial business. Formerly eight months were required to execute an order in India or China and obtain the return; now one day is sufficient. These commercial changes caused a revolution in the modes of business, and were the main factors which produced the monetary disturbances of 1873, the effects of which we yet feel, so long has it taken the world to adjust itself to its new relations.

*The future of commerce.*—The commerce of the world originated in Asia; it was carried to Africa and thence to Europe, and from Europe to America. This movement can go no farther westward, for on the other side of the Pacific is China, which has successfully resisted every attempt of the European to encroach upon her domains, and India with its teeming population of 250,000,000; so that America, the last of the continents to be inhabited, now receives the wealth of India and Asia pouring into it from the west, and the manufactures and population of Europe from the east. Here the east and west, different from each other in mental power and civilization, will meet, each alone incomplete, each essential to the fullest and most symmetrical development of the

other. Here will be the great banking and commercial houses of the world, the center of business, wealth, and population.

The end is not yet. Inventions are increasing in a geometric rather than an arithmetic progression. The limit of steam power has not been reached, for with a high temperature in a steam boiler the addition of a few pounds of coal increases the steam power so greatly that we are unable either to control or to use it.

Electricity has just begun to offer new opportunities to commerce. We are no longer compelled to carry our factories to the water power, for by the electric wire the power may be brought to the house of the operative, and we may again see the private workman supersede the factory operative. A few cars and small vessels are moved by electricity, the forerunner of greater things. We know little of this new agency, but its future growth must be more rapid and more wonderful than that of steam.

The Secretary of the Smithsonian Institution (Mr. Langley) tells us that "before the incoming of the twentieth century aërial navigation will be an established fact."

"The deeper the insight we obtain into the mysterious workings of nature's forces," says Siemens, "the more we are convinced that we are still standing in the vestibule of science; that an unexplored world still lies before us; and however much we may discover, we know not whether mankind will ever arrive at a full knowledge of nature."

# ON THE RELATION OF NATURAL SCIENCE TO ART.*

By Dr. E. du Bois-Reymond, F. R. S.

## I.

We are assembled to-day in annual commemoration of a man whose marvellous breadth of view and extraordinary variety of interests are each time a fresh surprise to us. It seems incredible that the same hand could have penned the "Protogea" and the state paper adjudging the Principality of Neufchatel to the King of Prussia, or that the same mind could have conceived the infinitesimal calculus and the true measure of forces, as well as the pre-established harmony and the "Theodicea." A closer examination however reveals a blank in the universality of his genius. We seek in vain for any connection with art, if we except the Latin poem composed by Leibnitz in praise of Brand's discovery of phosphorus. We need hardly mention that his "Ars Combinatoria" has nothing to do with the fine arts. In his letters and works observations on the beautiful are few and far between; once he discusses more at length the pleasure excited by music, the cause of which he attributes to an equable, though invisible, order in the chordal vibrations, which "raiseth a sympathetic echo in our minds." However, the world of the senses had little reality for Leibnitz. With his bodily eye he saw the Alps and the treasures of Italian art, but they conveyed nothing to his soul. He was indifferent to beauty; in short, we never surprise this Hercules at Omphale's distaff.

The same neglect, at least of sculpture and painting, strikes us in Voltaire, who as polyhistorian can in some measure compare with Leibnitz. We are obliged to descend as far as the third generation—that is, to Diderot in France, to Winckelmann and Lessing in Germany—before we meet with a decided interest in the fine arts and an appreciation of the part they play in the progress of civilization.

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* An address delivered at the annual meeting of the Royal Academy of Sciences of Berlin in commemoration of Leibnitz, on July 3, 1890. Translated by his daughter. This address was first printed in the weekly reports (*Sitzungsberichte*) of the Berlin Academy, then in Dr. Rodenberg's *Deutsche Rundschau*, and lastly it was published as a separate pamphlet by Veit & Co., at Leipzig, 1891. (From *Nature*, December 31, 1891, and January 7, 1892; vol. XLV, pp. 200-204, and 224-227.)

The period thus defined, though it excels in science, shows with few exceptions a falling off in the fine arts. On considering the historical development of these two branches of human productiveness we find no correspondence whatever between their individual progress. When Greek sculpture was in its prime, science scarcely existed. True, Leonardo's gigantic personality, which combines the immortal artist with the physicist of high rank, towers at the beginning of the epoch generally known in the history of art as the Cinquecento. Still, he was too far in advance of his age in the latter capacity to be cited as an example of simultaneous development in art and science; so little that Galilei was born the day of Michael Angelo's death. The mutual development in art and science at the commencement of our century is, I believe, merely a casual coincidence; moreover, the fine arts have since been, at the best, stationary, whereas science strides on victoriously toward a boundless future.

In fact, both branches differ too widely for the services rendered to science by art, and *vice versa*, to be other than external. "Nature," Goethe very truly observed to Eckermann—little thinking how harshly this remark reflects on part of his own scientific work—"Nature allows no trifling; she is always sincere, always serious, always stern; she is always in the right, and the errors and mistakes are invariably ours." Fully to appreciate the truth of this, one must be in the habit of trying one's own hand at experiments and observations while gazing in Nature's relentless countenance, and of bearing, as it were, the tremendous responsibility incurred by the statement of the seemingly most insignificant fact. For every correctly interpreted experiment means no less than this: Whatever occurs under the present circumstances would have occurred under the same conditions before an infinite negative period of time, and would still occur after an infinite positive period. Only the mathematician, whose method of research has more in common with that of the experimenter than is generally supposed, experiences the same feeling of responsibility in presence of Nature's eternally inviolable laws. Both are sworn witnesses before the tribunal of reality, striving for knowledge of the universe as it actually is, within those limits to which we are confined by the nature of our intellect.

However, there is a compensation for the philosopher, laboring under this anxious pressure, in the consciousness that the slightest of his achievements will carry him one step beyond the highest reached by his greatest predecessor; that possibly it may contain the germ of vastly important theoretical revelations and practical results, as Wollaston's lines contained the germ of spectral analysis; that, at any rate, such a reward is not only in the reach of a born genius, but of any conscientious worker; and, finally, that science, by subduing nature to the rule of the human intellect, is the chief instrument of civilization. No real civilization would exist without it, and in its absence nothing could pre-

vent our civilization, including art and its master works, from crumbling away again hopelessly, as at the decline of the ancient world.

This consciousness will also make up to the philosopher for the thoughtlessness of the multitude, who, while enjoying the benefits thus lavished upon them, hardly know to whom they owe them. The country rings with the name of every fashionable musical *virtuoso*, and cyclopedias insure its immortality. But who repeats the name of him who achieved that supreme triumph of the inventive intellect—to convey through a copper wire across far-stretching countries and over hill and dale the sound of the human voice as though it spoke in our ear?

"Life is earnest, art is gay;" this saying of Schiller's remains as true if we substitute science for life. Art is the realm of the beautiful; its productions fill us with an enjoyment, half sensuous, half intellectual; it is therefore a realm of liberty in the widest sense. No rigid laws are enforced in it; no stern logic binds the events of the present to those of the past and future; no certain signs indicate success; blame and praise are distributed by the varying taste of ages, nations, and individuals, so that the glorious Gothic church architecture came to be derided by the eighteenth century. In art, the definition of genius as a talent for patience does not hold good. Its creations, once brought forth in a happy hour of revelation, stir our souls with elementary force, and scorn all abstruse explanations, subsequently forced upon them by art criticism. Whoever accomplishes such a feat also ministers in a sense to the cares and troubles of humanity. Unfortunately the nature of things does not allow such fruit to ripen at all seasons; at one time, in one direction, the culminating point will be reached, and then age after age will strive in vain to emulate the past. The finest æsthetic theories can neither carry the individual beyond the limits of his own natural powers, nor retrieve the fortunes of a declining period. Of what use has been the recent strife in the artistic world between naturalists and idealists? Has it protected us from the frequently almost intolerable extravagances of the latter? There is an attraction in every boldly-advanced novelty which the common herd is unable to resist, and which will invariably triumph till antiquated ideas are somehow surplanted by fresh ones, or by the lofty rule of some irresistibly superior personality. Nor can science in the stricter sense come to the aid of art; and thus, strangers at heart, without materially influencing each other, each seeks its own way, the former advancing steadily, though irregularly, the latter slowly fluctuating like a majestic tide. Those unfamiliar with science are apt to recognize the supreme development of our mental faculties in art alone. Doubtless this is a mistake; yet human intellect shines brighest where glory in art is coupled with glory in science.

We may notice something here which is similar to what occurs in practical ethics. The more corrupt the morals of an age or nation, the more we find virtue a favorite topic. The flood of æsthetic theories rises highest when original creative power is at its lowest ebb. Lotze,

in his "History of Æsthetics in Germany," * gives a wearying and discouraging account of such fruitless efforts. Philosophers of all schools have revelled in absract definitions of the essence of beauty. They call it unity in multiplicity, or fitness without a purpose, or unconscious rationality, or the transcendant realized, or the enjoyment of the harmony of the absolute, and so forth. But all these properties, which are supposed to constitute the beautiful, have no more to do with our actual sensation of it than the vibrations of light and sound with the qualities they bring to our perception. Indeed, it would be vain to attempt to find one term equally fitted to describe all the varieties of the beautiful; the beauty of cosmos as contrasted with chaos, of a mountain prospect, a symphony, or a poem, of Ristori in Medea, or a rose; or even, taking the fine arts alone, the beauty of the Cologne Cathedral, the "Hermes" of Praxiteles, the Madonna Sistina, a picture of still-life, a landscape, a genre piece, or a Japanese flower design; not to mention the questionable custom which permits us in German to speak of a beautiful taste or a beautiful smell. Let us rather admit that here, as so often, we meet with something inexplicable in our organization; something inexpressible, though not the less distinctly felt, without which life would offer a dull and cheerless aspect.

In an essay of Schiller's there is a disquisition on physical beauty.† He distinguishes between an architectural beauty and a beauty which emanates from grace. I attacked this æsthetic rationalism, to which the last century was strongly addicted, twenty years ago on a similar occasion in a lecture on Leibnitz's ideas in modern science. I ventured to assert that "the attraction which physical beauty exerts on the opposite sexes can as little be explained as the effects of a melody."‡ On reflection, it seems indeed incomprehensible why one distinct shape, which, according to Fechner, might be represented by a plain algebraic equation between three variables, should please us beyond a thousand other possibilities. The reason can be traced from no abstract principle, no rules of architecture, not even from Hogarth's line of beauty. A year after this remark was made, Charles Darwin published his "Descent of man," in which the principle of sexual selection, only cursorily treated in the "Origin of Species," is fully expounded, and pursued in all its bearings. I remember vividly how, in a discussion with Dove as to the necessity of admitting a vital force, he embarrassed me by the objection that in the organic world luxury occurs, for example, in the plumage of a peacock or a bird of Paradise; while in inorganic nature Maupertuis's law of the minimum of action precludes such prodigality. Here was a solution of the problem, allowing that one might attribute to animals a certain sense of beauty. The gorgeous nuptial plumage displayed by male birds may have been acquired through the preference of

* Munich, 1868.

† "*Ueber Anmuth und Würde.*"

‡ The author's "*Collected Addresses*, etc," vol. I, pp. 49, 50, Leipzig, 1886.

the female for more highly ornamented suitors, a progeny of constantly increasing brilliancy of coloring being thus obtained. Male birds of Paradise have been observed to vie in showing off their beauty before the females during courtship. The power of song in nightingales might be attributed to the same cause, the female in this case being more susceptible to the charms of melody than to those of brilliant coloring. Darwin goes on to observe that, in the human race likewise, certain sexual characteristics, such as the imposing beard in man and the lovely tresses in woman, might have been acquired through sexual selection.* It is a well-known fact that, by repeated introduction of handsome Circassian slaves into aristocratic Turkish harems, the original Mongol type in many cases has been remarkably ennobled. And carrying the same principle further, we may find therein an explanation for the fascination which female beauty has for man. According to our present views, the first woman was not made of a rib taken out of the first man—a process fraught with morphological difficulties. It was man himself who, in countless generations, through natural selection, fashioned woman to his own liking, and was so fashioned by her. This type we call beautiful, but we need only to cast a glance at a Venus by Titian, or one by Rubens—let alone the different human races—to recognize how little absolute this beauty is.

If one kind of beauty could be said to bear analyzing better than another it is what might be termed mechanical beauty. It is noticed least, because it escapes all but the practiced eye. This kind of beauty may belong to machines or physical apparatus, each part of which is exactly fitted to its purpose in size, shape, and position. It answers more or less to the definition of "unconscious rationality," our satisfaction evidently proceeding from an unconscious perception of the right means having been employed to combine solidity, lightness, and, if necessary, mobility, with the greatest possible profit in the transmission of force and the smallest waste of material. A driving-belt is certainly neither attractive nor unattractive; but it pleases the "*risus eruditus*" to see a connecting-rod thicken from the ends towards the middle, where it has to bear the greatest strain. Of course, this kind of beauty is of recent origin. I remember Halske telling me that, as regards the construction of physical and astronomical instruments, it was, to his knowledge, first understood and established as a principle in Germany by Georg von Reichenbach in Munich. Berlin and Munich work-shops produced instruments of perfect mechanical beauty at a time when those supplied by France and England were still often dis-

* The author is not unaware of Mr. Wallace's attack on Darwin's explanation of the brilliant plumage of male birds by the females' preference, and of the discussion arisen between him and Messrs. Poulton, Pocock, and Peckham. This was not the proper place to enter into it, the less so as, whatever may be its outcome, the author's conclusion from the theory of sexual selection would remain unaltered.

figured by aimlessly ornamented columns and cornices, unpleasantly recalling the impure features of Rococo furniture and architecture.

I forget which French mathematician of the last century, in sight of the cupola of St. Peter's at Rome, tried to account for the sense of perfect satisfaction it gives to the eye. He measured out the curves of the cupola, and found that, according to the rules of higher statics, its shape supplies the exact maximum of stability under the given circumstances. Thus Michael Angelo, guided by an unerring instinct in the construction of his model (the cupola was not erected till after his death), unconsciously solved a problem the true nature of which he could hardly have understood, and which was even beyond the reach of the mathematical knowledge of his age. Apparently however there are several roots to this equation of beauty; at least, there is one other type, for which I quote the cupola of Val de Grâce in Paris, which, if not as imposing, is quite as gratifying to the eye as Michael Angelo's.

It will be observed that in this case mechanical beauty becomes part of the art of architecture; and instances of this kind are daily growing more frequent, our modern iron structures being more favorable to its display than stone buildings. In the Eiffel tower we see mechanical beauty struggling with the absence of plastic beauty. On this occasion it was probably revealed for the first time to many who hitherto had no opportunity of experiencing its effect. It is certainly not wanting in the new Forth Bridge. There is no doubt however that in stone structures too, together with much that pleases from habit or tradition, there are certain features which evidently attract through mechanical beauty—such as the outline of the architectural members of a building, or the gentle swelling and tapering of the Doric column towards the top, and its expansion in the echinus and abacus; and there are others which offend a refined taste through the absence of this beneficial element, such as the meaningless ornamentations of the Rococo style.

Even in organic nature mechanical beauty prevails to such an extent that it transforms many objects into a source of delight and admiration to the initiated, which are naturally repulsive to the untrained eye. Anatomists recognize it with pleasure in the structure of the bones, especially of the joints. In their opinion the "Dance of Death" outrages good taste from more reasons than because it differs from the classical conception of death. Mechanical beauty was already perceived by Benvenuto Cellini in the skeleton, much to his credit; and but for our imperfect knowledge it would invest with its glory every organic form, down to the inhabitants of the aquarium, even under the very microscope. According to Prof. Schwendener, even plants are constructed on the same principle of fitness combined with thrift; and something of this we feel at sight of a spreading oak tree proudly distending its vigorous branches towards air and sunlight.

Again, our appreciation of the forms of animals, especially of noble

breeds, is greatly influenced by mechanical beauty. The greyhound and the bulldog, the full-bred race horse and the brewer's dray horse, the Southdown and the Merino sheep, the Alpine cattle and the Dutch milch cow, all are beautiful in their kind, even though a bulldog or a Percheron may appear ugly to the uninitiated, because in each the type of the species has been modified to the utmost degree of fitness.

Though science is unable, as we have seen, to check the occasional decline of art and inspire it with fresh vigor, yet it renders invaluable services of a different kind to artists by increasing their insight, improving their technical means, teaching them useful rules, and preserving them from mistakes. I do not allude to anything so primitive as the manufacture of colors or the technique of casting in bronze; the less so, as curiously enough our modern colors are less durable than those of entirely unscientific ages, and the unsurpassed thinness of the casting of Greek bronzes is regarded as a proof of their authenticity. Nor does it seem necessary to recall the notorious advantages of this kind for which art is indebted to science. Linear perspective was invented by Leonardo and Dürer—artists themselves. It was followed by the laws of reflection—unknown to ancient painters, as would appear from the Pompeian frescoes of Narcissus—and by the geometrical construction of shadows. The rainbow, which had better not be attempted at all, has been sinned against cruelly and persistently by artists, in spite of optics. Statics furnished the rules of equilibrium so essential to sculptors. Aërial perspective, again, owes its development to painters chiefly of northern climates.

But to this fundamental stock of knowledge the progress of science has added various new and important acquisitions, which philosophers, some of first-rate ability, have endeavored to place within the reach of artists. The great masters of bygone ages were taught by instinct to combine the right colors, as women of taste, according to John Müller, always know how to blend the right shades in their dress; and Oriental carpet weavers have not been behindhand with them in that respect. But the reason why they unconsciously succeed was not revealed till the elder Darwins, Goethe, Purkinye, John Müller, and others called into existence a subjective physiology of the sense of sight. A member of this academy, Prof. von Brücke, in his "Physiology of Colors"* and "Fragments from the Theory of the Fine Arts in relation to Industrial Art,"† treats these subjects with such intimate knowledge as could only be obtained by one who enjoyed the rare advantage of combining physiological learning with an artistic education acquired in his father's studio. In France Chevreul pursued similar aims. Even Prof. von Helmholtz, in his popular lectures, has devoted his profound knowledge of physiological optics to the service of art, which already owes him important revelations on the nature of musical harmony. Amongst

* 2d edition, Leipzig, 1887.

† Leipzig, 1877.

other things, he explained the relation between the different intensities of light in objects of the actual world and those on the painter's palette, and pointed out the means by which the difficulties arising therefrom may be overcome.* Thus painters, as von Brücke remarks, have it in their power to reproduce the dazzling effect of the disk of the sun by imitating the irradiation—a defect of our visual perception, the true nature of which was recognized by von Helmholtz. An example of this, interesting through its boldness, is the lovely Castell Gandolfo in the Raczynski gallery.

There are so many and striking instances of such imperfections of the human eye that, notwithstanding its marvellous capabilities, von Helmholtz has observed that "he would feel himself justified in censuring most severely the careless workmanship of an optician who offered him for sale an instrument with similar defects, and that he would emphatically refuse to take it." The eye being the chief organ of artists, its defects are of great importance in art and its history, and artists would do well to inform themselves not only on these defects in general, but more particularly on those which they, in their own persons, are subject to; for, as Bessel remarked of astronomical instruments, "an error once well ascertained ceases to be an error."

Our conception of the stars as stars, in the shape adopted symbolically by decorative art, is caused by a defect of the eye closely related to irradiation, stars being luminous spots in the sky without rays, as they actually appear to a privileged few. Prof. Exner, whose line of thought we shall repeatedly cross in the course of these reflections, justly remarks that to this imperfection the stars conferred by sovereigns as marks of distinction owe their origin and starfishes their name even since Pliny's time. The different varieties of halo, however, are more probably freeborn children of our fancy—from the Byzantine massive golden disk down to the mild phosphorescence proceeding from holy heads and in Correggio's "Night" from the entire child, which illumines the scene with a light of its own. According to Prof. Exner, glories of the latter description are derived from the radiance which surrounds the shadow of one's own head in the sunshine on a dewy meadow, and which in fact has always been compared to halos in religious pictures. This phenomenon even misled Benvenuto Cellini into the pious delusion that it was a gift granted him individually from above, and a reflection of his visions, such as Moses brought down from Mount Sinai.†

Certain otherwise quite inexplicable peculiarities which disfigure the later works of the distinguished landscape painter Turner have also been traced to defects of the eye by Dr. Richard Liebreich.‡ Clouded

* Prof. von Helmholtz, *Collected Essays and Addresses*, vol. II, Brunswick, 1884.

† "*Vita di Benvenuto Cellini*, scritta da lui medesimo," libro primo, CXXVII.

‡ Turner and Mulready: *The Effect of certain Faults of Vision on Painting*, &c. London. 1888.

lenses or a high degree of astigmatism might easily lead a painter to distort or blur objects he was copying from nature. Donder's stenoptic spectacles or cylindrical spectacles, as the case might be, would prove as useful to such an artist as concave glasses to the short-sighted.

The singularities of another English painter, Mulready, are accounted for by Dr. Liebreich through discoloration of the lens from old age. Another defect of the eye, color-blindness, ought to be mentioned here, which in its milder forms is of frequent occurrence, and even belongs to the normal condition of the eye on the borders of the field of vision. It corresponds in the domain of hearing to the want of musical ear. Color-blindness was known long ago, but has been inquired into with redoubled zeal latterly, partly with regard to its general connection with chromatics, partly on account of its serious practical consequences in the case of sailors, railway officials, and, as Dr. Liebreich adds, of painters. Both color-blindness and want of ear are inborn defects, for which there is no remedy. A color-blind artist is however better off than a musician without an ear, if such a one were imaginable, for, even if he neglected the mahl-stick and the chisel, he might still seek his fortune in the designing of cartoons.

It is difficult to determine the particular point where optical knowledge ceases to be of use to artists. None will repent having studied the laws of the movement of the eyes, the difference between near and distant vision, and the observations on the expression of the human eye contained in John Müller's early work on "Comparative Physiology of Sight." Yet it must be admitted that a painter may paint an eye exceedingly well without ever having heard of Sanson's images, which cause the soft luster of a gentle eye as well as the fierce flash of an angry one; as little as the blue sky of a landscape painter will gain by his knowledge of the yellow brushes in every great circle of the heavenly vault which passes through the sun—a phenomenon which has remained unnoticed for countless ages, but has grown familiar to physiologists since Haidinger's discovery.

One point, however, where physicists seem to me not to have been sufficiently consulted is the much-debated question of polychrome in ancient statues and architecture, and whether it should be adopted by modern art or not. Physical experiments teach that very intense illumination causes all colors to appear whitish; in the spectrum of the sun, seen immediately through the telescope, the colors vanish almost entirely, nothing remaining except a light yellow hue in the red end. As the colors grow whitish the glaring contrasts are softened, they blend more harmoniously. In the open air, therefore, our eye is not shocked by the scarlet skirt of the *contadina*, which recurs almost as invariably in Oswald Achenbach's Campagna landscapes, as the white horse in Wouvermann's war scenes. The Greek statues and buildings may have looked well enough with their glaring decorations under the bright southern sky on the Acropolis or in the Poikile; in the dull light

of our northern home, above all in closed rooms, they are somewhat out of place.

In another direction Wheatstone has added valuable information to the knowledge of painters and designers with his stereoscope. It demonstrates the fundamental difference which distinguishes binocular vision of near objects from monocular vision, as well as from binocular vision of objects so far removed that the distance between the eyes vanishes as compared with their distance. An impression of solidity can only be obtained by each eye getting a different view of an object, the two images being fused into one, so as to appear solid. A painter can therefore only express depth by shading and aërial perspective; he will never be able to produce the impression of actual solidity on his canvas. While Wheatstone's pseudoscope exhibits the unheard-of spectacle of a concave human face, Helmholtz's tele-stereoscope magnifies, as it were, the space between the eyes, and resolves a far-off range of woods or hills without aërial perspective into its different distances. Finally, Halske's stereoscope, with movable pictures, confirms old Dr. Robert Smith's explanation of the much-debated circumstance that the sun and moon on the horizon appear larger by almost a fifth of their diameter than when seen in the zenith, and reduces the problem to the other question: why the vault of the sky appears to us flattened instead of hemispherical.

However, the almost contemporary invention of photography was destined to be of vastly greater importance to the fine arts. It had always been the dream of artists as well as physicists to fix Della Porta's charming pictures—a dream the realization of which did not seem quite impossible since the discovery of chloride of silver. One must have witnessed Daguerre's invention, and Arago's report of it in the Chamber of Deputies, to conceive the universal enthusiasm with which it was welcomed. Daguerre's method, being complicated and of restricted application, was soon cast into the shade by the one still essentially practiced at the present day. However, it is worth recording that, when the first specimens, imperfect as they were, reached us from England, no one foresaw the immense success in store for Talbotypes; on the contrary, the change from silver-coated plates to paper impregnated with the silver salt was received with doubt and considered a retrogression.

Thus photography entered on its marvellously victorious career. With respect to art, it promptly fulfilled what Arago had promised in its name. It not only facilitated the designing of architecture, interiors, and landscapes, and rendered the camera clara unnecessary even for panoramas, but also furnished many valuable hints with regard to light and shade, reflection and chiaroscuro, and the general means of reproducing as closely as possible on a level surface the raised appearance of solid forms. A competent judge of both arts might find it an interesting task to ascertain what share photography has had in

the origin of the modern schools of painting and in the manner of impressionists and pleinairists. It further taught landscape painters to depict rocks and vegetation with geological and botanical accuracy, and to represent glaciers, which hitherto had been but rarely and never successfully attempted. It caught and fixed the changing aspect of the clouds, though only yielding a somewhat restricted survey of the heavens. It aided portrait painters, without exciting their jealousy; for, unable to rival them in representing the average aspect of persons, it only seized single, often strained and weary, expressions, rendering almost proverbial the comparison between a bad portrait and a photographed face; nevertheless it supplied them on many occasions with an invaluable groundwork, lacking nothing but the animating touch of an artist's hand.

However, the recent progress of photographic portraiture claims the attention of artists in more than one respect. Duchenne and Darwin called into existence a new doctrine of the expression of the emotions; the former by galvanizing the muscles of the face, in order to imitate different expressions, the latter by inquiring into their phylogenetic development in the animal series. Both presented artists with photographs which quickly consigned to oblivion the copies hitherto employed for purposes of study in schools of art, dating chiefly from Lebrun; even the sketches in Signor Mantegazza's new work on "Physiognomy and Mimics" will scarcely enter into competition. On Mr. Herbert Spencer's suggestion Mr. Francis Galton subsequently solved by the aid of photography a problem which was previously quite as inaccessible to painters as the representation of an average expression to photographers. He combined the average features of the face and skull of a sufficient number of persons of the same age, sex, profession, culture, or disposition to disease or vice in one typical portrait, which exhibits only those characteristic forms common to their various dispositions. This was effected by blending on one negative the faint images of a series of persons belonging to the same description. In the same manner Prof. Bowditch, of Harvard Medical School, Boston, obtained the representative face or type of American students of both sexes and of tramway conductors and drivers. In the latter instance the intellectual superiority of the conductors over the drivers is plainly visible. How Lavater and Gall would have relished this!

Of course the average expression of a single person might be procured by similar means, if it were worth while summing up on the same plate repeated photographs of different expressions. Instantaneous photography, however, furnishes a welcome substitute for the average expression, by seizing with lightning swiftness the changing phases of the human countenance in their full vivacity. Here again pathology places itself at the disposal of art. M. Charcot has found that photographs of the convulsions and facial distortions of hysterical patients resemble our classical representations of the possessed. Raphael's

realism in this respect is perhaps the most curious of all, being so much at variance with his idealistic nature. In the possessed boy of the "Transfiguration" a cerebral disease can be almost safely inferred from the Magendie position of the eyes, and the circumstance, recently observed in New York, that the left hand is depicted in a spasm of athetosis would accord well with this diagnosis.*

## II.

There is yet another direction in which art owes instructive disclosures to the progress of photography. In the year 1836, the Brothers William and Edward Weber represented, in their celebrated work on the "Mechanism of the Human Locomotive Apparatus," a person in the act of walking in those attitudes which according to theoretical calculation must occur successively during one step. Thence a strange fact became apparent. At the beginning and end of each step, while the body rests for a short time on both feet, the pictures agree perfectly with the ordinary way in which painters have been accustomed to represent walking persons. But during the middle of the step, while one foot is swinging past the other, the effect is highly eccentric, not to say ludicrous. The individual appears to be stumbling over his own feet like a tipsy fiddler, and nobody had ever been seen walking in such a way. On the last page of their book the Brothers Weber propose to test the correctness of their diagrammatic figures by the aid of Stampfer & Plateau's stroboscopic disks in the shape of Horner's Dædaleum,† which has (strange to say) returned to us from America as a new invention, under the name of "zoëtrope" or even "vivantoscope;" but whether the proposal was carried out or not does not appear.

However, William Weber lived to see his assertions thoroughly justified almost half a century later by instantaneous photography. It was first put into practice in 1872 by Mr. Eadweard Muybridge at the suggestion of Mr. Stanford, in order to fix the consecutive attitudes of horses in their different paces. The result was the same as in Weber's diagrammatic figures; pictures were obtained which nobody could believe to have been seen in reality. On photographs of street life and processions the camera frequently surprised people in attitudes quite as odd as those attributed to them by the brothers Weber on theoretical grounds. The same is the case with the remarkable series of photographs of a flying bird during one beat of its wings, obtained by M. Marey with his photographic gun.

The explanation is known to be as follows: An object in motion, the speed of which varies periodically, leaves a deeper and more lasting

* Sachs & Petersen, "A Study of Cerebral Palsies," etc., *Journal of Nervous and Mental Diseases*, New York, May, 1890.

† *Philosophical Magazine*, January, 1834, 3d series, vol. II, p. 36.

impression on our mind in those positions which it occupies longest, while the impression is fainter and more fleeting in those through which it passes quickly. Apart from all knowledge of this law, a painter would never represent a Dutch clock in a cottage with the pendulum at the perpendicular, as every spectator would inquire why the clock had been stopped. The pendulum, having swung in one direction, necessarily stops for a moment while preparing to return in the other, and consequently its diverging position is more vividly stamped on our minds than those during which it passes through its position of rest with a maximum of speed. Precisely the same thing occurs with the alternately swinging legs of a man during the act of walking; the body remains longest in the position in which both feet support it, and shortest in that during which one foot swings past the other. We therefore receive scarcely any impression from the latter series of attitudes. We imagine a walking person, and painters accordingly represent him, in the interval between two steps, with both feet touching the ground.

In the case of a running horse, however, particular circumstances intervene. However rapid the succession of instantaneous photographs, we never obtain the usual image of a racing horse such as it appears in large numbers in the print-shops at the racing season, and such as we suppose we actually see in reality. It is different in the case of man; there among pictures obtained methodically or by chance, which have, so to speak, never been perceived by the naked eye, some will always occur which agree with the usual aspect of a walking person. The difference consists in this, that in a racing horse the interval of time, during which the fore legs remain in complete extension, does not coincide with that during which the hind legs are fully extended. Both these positions prevailing in our memory, they are subsequently blended into the traditional picture of a race horse, whereas instantaneous photography fixes them successively. Consequently the traditional picture is wrong, and exhibits the horse in a position through which it does not even transitorily pass.

In the year 1882, an illustrated American paper brought out a picture of a steeple-chase, in which all the horses are copied from Muybridge's photographs, in attitudes only visible to a rapid plate. This ingenious sketch was communicated to us by Prof. Eder in Vienna, in a pamphlet on instantaneous photography, and a stranger spectacle can not well be imagined. The correctness of these apparently wrong pictures can however be proved by realizing the idea originally suggested by the brothers Weber, and integrating into a general impression the periodical motion which has been resolved, as it were, into differential pictures. This is done by gazing in the dædaleum at a series of photographs taken at sufficiently brief intervals from an object in periodical motion, or illuminating or projecting it momentarily during its rapid flight past the eye. The latter method has been put into practice by

Mr. Muybridge himself in his "zoopraxiscope," and with us in the electric stroboscope by Mr. Ottomar Anschütz, a most skillful handler of instantaneous photography. In both instruments we see men and horses reduced to their natural mode of walking, running, or jumping—with one exception. The speed with which the slits of the dædaleum pass before the eye, or the period during which each picture is illuminated, being exactly the same for the whole series, the general effect produced is somewhat different from what it would be in real life. On the whole, however, the position in which both feet are touching the ground, prevails, because the motion of the legs slackens when approaching this position, so that the pictures follow each other more closely and almost coincide.

The series of instantaneous photographs taken by Mr. Muybridge and Mr. Anschütz from an athlete, during the performance of a muscular effort, are an inexhaustible source of instruction to students of the nude. Mr. Anschütz's stroboscope exhibits a stone and a spear-thrower in all the different stages of their violent action; their muscles are seen to swell and slacken, until finally the missile is represented after its discharge, as it can not move any faster than the hand in the act of hurling it. Animal painters will find equally useful the instantaneous photographs which Mr. Muybridge and Mr. Anschütz have obtained from domestic and wild animals.

Even on breakers in a stormy sea the camera has been employed with surprising success. In making use of these photographs, painters should, however, remember that the human eye can not see the waves as a rapid plate does, and beware of producing a picture which in certain respects would be quite as incorrect as the clock which appears to have been stopped, or the man stumbling over his own feet.

Finally, the traditional representation of lightning in the shape of a fiery zigzag has been recently proved by Mr. Shelford Bidwell, on the evidence of two hundred instantaneous photographs, to be just as wrong as the traditional picture of a racing horse. Mr. Eric Stuart Bruce endeavors to vindicate the zigzag by taking it for a reflection on cumulus clouds; * it is, however, difficult to understand how its sharp angles can be accounted for in this way.

Prof. von Brücke has devoted a special essay to the rules for the artistic rendering of motion, which, together with the laws on the combination of colors, have at all times been unconsciously followed by the great masters.

A cultivated and artistically gifted eye, supported by sufficient technical knowledge, was always able to compose genuine works of art in photography, as Mrs. Cameron long ago proved. In our days, Dr. Vianna de Lima has shown how this branch of art has been advanced and extended by instantaneous photography. It contributes a solution

* *Nature*, vol. XLII, pp. 151 and 197.

to Conti's question in Lessing's "Emilia Galotti"—whether Raphael, had he been born without hands, would not the less have been the greatest of painters. The photographic plate has been described as the true retina of the philosopher; and one might add, of the artist, if it were not unluckily almost color-blind. Unfortunately, theoretical reasons which experience will hardly contradict render it highly improbable that the expectations still entertained by artists and the general public, with regard to photography in natural colors, will ever be realized.

Whether photography does not act unfavorably on the reproductive arts, such as engraving, lithography, and woodcutting, by taking their place to an increasing extent, remains to be proved. Its fidelity is certainly such as, in a certain sense, to lower the value of the original drawings of old masters, by making them common property. An exhibition, arranged by one of our art-dealers several years ago, of the best engravings of the "Madonna della Sedia," together with a photograph from the original, first opened our eyes to the extent to which each master has embodied in his copy his own individual conception. But even were photography to cause such a retrogression in the reproductive arts, of what importance would that be, compared to the immeasurable services which, as a means of reproduction itself, it renders art, by disseminating the knowledge and enjoyment of artistic work of all kinds and periods? No one can fully estimate and appreciate what it has done to beautify and enrich our life, whose memory does not reach back into those, as it were, prehistoric times, "when man did not yet travel by steam, write and speak by lightning, and paint with the sunbeam."

Is it credible, after all this, that there can be any need of mentioning the benefits derived by art from the study of anatomy? Has not the "Gladiator" of the Palazzo Borghese given rise to the conjecture that there were anatomical mysteries among the Greek artists, as the only means by which they could have obtained such complete mastery of the nude? Was it not through incessant anatomical studies that Michael Angelo acquired the knowledge necessary for the unprecedented boldness of his attitudes and foreshortenings, which are still a source of admiration to anatomists such as Prof. Henke and Prof. von Brücke? Has not provision been made by all governments that methodically encourage art to afford to students an opportunity of training the eye on the dead subject to note what they will have to distinguish under the living skin? Have not three successive teachers, who afterwards became members of this academy, been intrusted with this important duty in Berlin? Finally, do we not possess excellent compendiums of anatomy specially adapted to the use of artists?

And yet the most renowned English art critic of the day, who in his country enjoys the reputation and veneration of a Lessing, and who lays down the law with even more assurance—Mr. John Ruskin—explicitly forbids his pupils the study of anatomy in his lectures on

"The Relation of Natural Science to Art,"* given before the University of Oxford. Even in the preface he deplores its pernicious influence on Mantegna and Dürer, as contrasted with Botticelli and Holbein, who kept free from it. "The habit of contemplating the anatomical structure of the human form," he continues, "is not only a hindrance, but a degradation, and has been essentially destructive to every school of art in which it has been practiced." According to him, it misleads painters, as for instance Dürer, to see and represent nothing in the human face but the skull. The artist should "take every sort of view of animals, in fact, except one—the butcher's view. He is never to think of them as bones and meat."

It would be waste of time and trouble to refute this false doctrine, and to set forth what an indispensable aid anatomy gives to artists, without which they are left to grope in the dark. It is all very well to trust one's own eyes, but it is better still to know, for instance, how the male and female skeleton differ; why the kneecap follows the direction of the foot during extension, and not during flexion of the leg; why the profile of the upper arm during supination of the hand differs from that during pronation; or how the folds and wrinkles of the face correspond to the muscles beneath. Campe's facial angle, though superceded for higher purposes by Prof. Virchow's basal angle, still reveals a world of information. It is hardly conceivable how, without knowledge of the skull, a forehead can be correctly modelled, or the shape of a forehead such as that of the "Jupiter of Otricoli" or the "Hermes" be rightly understood. Of course fanciful exaggeration of anatomical forms may lead to abuse, as is frequently the case with Michael Angelo's successors; however, there is no better remedy against the Michael Angelesque manner than earnest study of the real. Finally, a superficial knowledge of comparative anatomy helps artists to avoid such errors as an illustrious master once fell into, who gave the hind-leg of a horse one joint too many; or such as amuses naturalists in the crocodile of the Fontaine Cuvier near the Jardin des Plantes, which turns its stiff neck so far back that the snout almost touches the flank.

We are, however, less surprised at Mr. Ruskin's opinions, on learning that he similarly prohibits the study of the nude. It is to be confined to those parts of the body which health, custom, and decency permit to be left uncovered, a restriction which certainly renders anatomical studies somewhat superfluous. It is satisfactory to think that decency, custom, and health allowed the ancient Greeks more liberty in this respect. Fortunately, the English department of the Berlin International Exhibition four years ago has convinced us that Mr. Ruskin's dangerous paradoxes do not yet generally prevail, and that we are free to forget them in our admiration of Mr. Alma Tadema's and Mr. Herkomer's paintings. Nor could Mr. Walter Crane's charm-

* "The Eagle's Nest: Ten Lectures on the Relation of Natural Science to Art," 1887.

ing illustrations, the delight of our nurseries, have been produced without disregard of Mr. Ruskin's preposterous doctrine.

In the same lecture Mr. Ruskin opposes with the utmost vehemence the theory of evolution and natural selection, and the æsthetic rule founded on it, according to which vertebrate animals should not be represented with more than four legs. "Can any law be conceived," he says, "more arbitrary, or more apparently causeless? What strongly planted three-legged animals there might have been! what systematically radiant five-legged ones! what volatile six-winged ones! what circumspect seven-headed ones! Had Darwinism been true, we should long ago have split our heads in two with foolish thinking, or thrust out, from above our covetous hearts, a hundred desirous arms and clutching hands, and changed ourselves into Briarean Cephalopoda."

Obviously, this false prophet has no notion of what in morphology is called a type. Can it be necessary to remind a countryman of Sir Richard Owen and Prof. Huxley that the body of every vertebrate animal is based on a vertebral column, from which it derives its name, expanding at one end into a skull, reduced to a tail at the other, and surrounded before and behind by two bony girdles, the pectoral and the pelvic arches, from which depend the fore and hind limbs, with their typical joints? The very fact that paleontology has never known any form of vertebrate animal to depart from this type is in itself a striking argument in favor of the doctrine of evolution and against the assumption of separate acts of creation, there being no reason why a free creative power should have thus restricted itself. So little will nature deviate from the type once given that even deformities are traced back to it by teratology. They are not really monstrosities; not even those with a single eye in the middle of the forehead, which Prof. Exner takes to be prototypes of the Cyclops, Flaxman being certainly mistaken in representing Polyphemus with three eyes—two normal ones which are blind, and a third in the forehead. Real monstrosities are those winged shapes of Eastern origin, invented by a riotous fancy while art was in its childhood; the bulls of Nimrûd, the Harpies, Pegasus, the Sphinx, the griffin, Artemis, Psyche, Notos of the Tower of Winds, the goddesses of Victory, and the angels of Semitic-Christian origin. A third pair of extremities (Ezekiel even admits a fourth), is not only contrary to the type, but also irrational in a mechanical sense, there being no muscles to govern them. In the "Fight with the Dragon" Schiller has happily avoided giving his monster the usual pair of wings; and in Retzsch's illustrations its shape agrees so far with comparative anatomy as to recall a Plesiosaurus or Zeuglodon returned to life and changed into a land animal; indeed, the resemblance between those animals and the mythical dragon has led to the question whether the first human being might not have actually gazed upon the last specimens of those extinct animal races.

An abomination closely related to the winged beasts are the Centaurs, with two thoracic and abdominal cavities and a double set of viscera; the Cerberus and Hydra, with several heads on as many necks; and the warm-blooded Hippocamps and Tritons, whose bodies, destitute of hind limbs, end in cold-blooded fish—an anomaly which already shocked Horace. If they had at least a horizontal tail fin they might pass for a kind of whale. The cloven-footed faun is less intolerable; from him our Satan inherited his horns, pointed ears, and hoofs, on account of which Cuvier, in Franz von Kobell's witty apologue, ridicules him as an inoffensive vegetable feeder. The heraldic animals, such as the double eagle and the unicorn, have no artistic pretensions, and their historical origin entitles them to an indulgence they would otherwise not deserve.

It is a remarkable instance of the flexibility of our sense of beauty that, though saturated with morphological principles, our eye is no longer offended by some of these monstrosities, such as the winged Nike and the angels; and it would perhaps be pedantic, certainly ineffectual, to entirely condemn these traditional and more or less symbolical figures, though in fact the greatest masters of the best epochs have made very slight use of them. There are however limits to our toleration. Giants, as they occur in our Gigantomachia, with thighs turning half way down into serpents, which consequently rest, not upon two legs, but upon two vertebral columns ending in heads and endowed with special brains, spinal cords, hearts, and intestinal canals, special lungs, kidneys, and sense organs—these are, and always will be, the abhorrence of every morphologically trained eye. They prove that, if the sculptors of Pergamon surpassed their predecessors of the Periclean era in technical skill, they were certainly second to them in artistic refinement. Perhaps they should be excused on the plea that tradition bound them to represent the giants with serpent legs. The Hippocamps and Tritons, with horses' legs and fish tails, which disfigure our Schlossbrücke, date from a period in which classical taste still reigned supreme, and morphological views were still less widely diffused than at present. Let us therefore pardon Schinkel for designing or at least sanctioning them, as well as the winged horse and griffin on the roof of the Schauspielhaus, for which he must also be held responsible. But our indignation is justly aroused when a celebrated modern painter depicts with crude realism such misshapen male and female monsters wallowing on rocks, or splashing about in the sea, their bodies ending in fat shiny salmon, with the seam between the human skin and the scaly cover scantily disguised. Such ultramarine marvels are worshipped by the crowd as the creations of genius; then what a genius Höllen-Breughel must have been!

Curiously enough, the inhabitants of the caves of Périgord, the contemporaries of the mammoth and musk ox in France, and the bushmen whose paintings were discovered by Prof. Fritsch, only represented as

faithfully as possible such animals with which they were familiar; whereas the Aztecs, a people of comparatively high civilization, indulged in fancies of more than Eastern hideousness. It would almost appear as if bad taste were associated with a middle stage of culture.

With regard to the teaching of anatomy in schools of art, the above proves that it should not be confined to human osteology, myology, and the doctrine of locomotion alone, but that it should also endeavor—and the task is not difficult—to familiarize the student with the fundamental principles of vertebral morphology.

Botanists should in their turn point out such violations of the laws of the metamorphosis of plants as must, no doubt, frequently strike them in the acanthus arabesques, palmettos, rosettes, and scrolls handed down to us from the ancients. For obvious reasons, however, these can not affect them as painfully as malformations of men and animals, being in themselves repulsive to natural feelings, would the comparative anatomist. Moreover, a beneficial revolution has recently taken place in floral ornament. The displacement of Gothic art by the antique during the Renaissance had led to a dearth of ideas in decorative art. The rich fancy and naive observation of nature displayed upon the capitals of many a cloister had gradually given way to a fixed conventionalism no longer founded on reality. Rauch, at Carrara, in search of a model for the eagles on his monuments, was the first to turn to a golden eagle, accidentally captured on the spot, instead of to one of the statues of Jupiter. It was then that, towards the middle of the century, decorative art began to shake off its fetters, and, combining truthfulness with beauty, returned to the study and artistic reproduction of the living plants with which we are surrounded. In this respect the Japanese had long ago adopted a better course, and to them we have since become indebted for many suggestions. Thus highly welcome additions were made to the decoration of our homes and the ornaments of female dress.

In one direction, however, it will be observed that men of science readily dispense with a strict observation of the laws of nature in art, at the risk of being charged with inconsistency. In works of art, both ancient and modern, flying and soaring figures occur in thousands. These, no doubt, sin against the omnipotent and deeply felt laws of gravity quite as much as the most loathsome creations of a depraved imagination against the principles of comparative anatomy, familiar only to a few adepts. Nevertheless they do not displease us. We prefer them without wings, because wings are contrary to the type, and could be of no use to them without an enormous bulk of muscle. But we do not mind the Madonna Sistina standing on clouds and the subordinate figures kneeling on the same impossible ground. "Ezekiel's Vision" in the Palazzo Pitti is certainly less acceptable. But to quote modern examples, Flaxman's "Gods flying to the aid of the Trojans," or Cornelius's Apocalyptical riders, and Ary Scheffer's divine Francesca

di Rimini, with which Doré had to enter into hopeless competition, are not the less enjoyable because they are physically impossible. We do not even object to Luini's representing the corpse of St. Catharine carried through the air by angels, or to that of Sarpedon, in Flaxman's drawing, by Sleep and Death.

In an interesting lecture on the "Physiology of Flying and Soaring in the Fine Arts," Prof. Exner endeavors to explain why illustrations of men and animals in this condition, though impossible and never visible in real life, strike us as familiar and natural. I do not profess to agree entirely with the solution which he appears to prefer. His idea is that our sensations in swimming, and the position in which we see persons above us in the water when diving, are similar to what we would experience in flying. Considering what a short time the art of swimming has been generally practiced by modern society, especially by ladies, who nevertheless appreciate flying figures just the same, doubts arise as to the correctness of Prof. Exner's explanation. To attribute the feeling to atavism in a Darwinian sense, dating from a fish period in the development of man, seems rather far-fetched. And do not the sensations and aspect of a skater come much nearer to flying or soaring than those of a swimmer?

Another remark of Prof. Exner, which had also occurred to me, appears more acceptable. It is, that under especially favorable bodily conditions we experience in our dreams the delicious illusion of flying. For

> "in each soul is born the pleasure
> Of yearning onward, upward, and away,
> When o'er our heads, lost in the vaulted azure,
> The lark sends down his flickering lay,
> When over crags and piny highlands
> The poising eagle slowly soars,
> And over plains and lakes and islands
> The crane sails by to other shores."*

Who would not long, like Faust, to soar out and away towards the setting sun, and to see the silent world bathed in the evening rays of eternal light far beneath his feet? And when we long for anything, we love to hear of it, and to see it brought before us in image. Our desire to rise into the æther, and our pleasure in "Ascensions" and similar representations, are further enhanced by the ancient belief of mankind in the existence of celestial habitations for the blessed beyond the starry vault; a belief which Giordano Bruno put an end to, though not so thoroughly but that we are constantly forgetting how badly we should fare, were we actually to ascend into those vast, airless, icy regions, which even the swiftest eagle would take years to traverse before alighting on some probably uninhabitable sphere.

We are now inclined to reverse the question, and to ask: What have sculpture and painting been able to do for science in return for its vari-

*Translation of Goethe's "Faust," by Bayard Taylor.

ous services? With the exception of external work, such as the representing of natural objects, not much else than the results obtained by painters as to the composition and combination of colors, which, however, have not exercised as strong an influence on chromatics as music on acoustics. It is known that the Greeks possessed a canon of the proportions of the human body, attributed to Polycletes, which, as Prof. Merkel recently objected, unluckily only applied to the full-grown frame, to the detriment of many ancient works of art. The blank was not systematically filled up till the time of Gottfried Schadow. This canon has since become the basis of a most promising branch of anthropology—anthropometry in its application to the human races.

If the definition of art were stretched so far as to include the power of thinking and conceiving artistically, then, indeed, it would be easy enough to find relations and transitions between artists and philosophers, though, as we remarked at the beginning, their paths diverge so completely. But it is not so certain that natural science would necessarily be benefited by an artistic conception of its problems. The aberration of science at the beginning of this century, known as German physiophilosophy owed its origin quite as much to æsthetics as to metaphysics, and the same erroneous principles guided Goethe in his scientific researches. The artistic conception of natural problems is in so far defective as it contents itself with well-rounded theoretical abstractions instead of penetrating to the causal connection of events to the limits of our understanding. It may suffice in cases where analogies are to be recognized by a plastic imagination between certain organic forms, such as the structure of plants or vertebrate animals; but it fails altogether in subjects, such as the theory of colors, because it stops short at the study of what are supposed to be primordial phenomena instead of analyzing them mathematically and physically. Prof. von Brücke subsequently, by the aid of the undulatory theory, traced to their physical causes the colors of opaques on which Goethe founded his theory of colors and which to this day have tended rather to darken than to enlighten certain German intellects. The difference between artistic and scientific treatment becomes very evident in this example.

Nevertheless, it can not be denied that artistic feeling may be useful to scientific men. There is an æsthetic aspect of experiment which strives to impart to it what we have termed mechanical beauty; and no experimenter will regret having responded to its demands as far as was in his power. Moreover, the transition from a literary to a scientific epoch in the intellectual developement of nations is accompanied by a tendency to brilliant delineation of natural phenomena, arising from the double influence of the setting and the dawning genius. Instances thereof are Buffon and Bernardin de Saint-Pierre in France, and Alexander von Humboldt in Germany, who, to his extreme old age, remained faithful to this tendency. In the course of time, this somewhat incongruous mixture of styles splits into two different manners. Pop-

ular teaching preserves its ornamental character, while the results of scientific research only claim that kind of beauty which in literature corresponds to mechanical beauty. In this sense, as I long ago ventured to indicate here on a similar occasion, a strictly scientific paper may, in tasteful hands, be made as finished a piece of writing as a work of fiction. To strive after such perfection will always repay the trouble to men of science; for it is the best means of testing whether a chain of reasoning, embracing a series of observations and conclusions, is faultlessly complete.

And this kind of beauty, which often graces, unconsciously and unsought for, the utterances of genius, will no doubt be also found to adorn Leibnitz's writings.

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